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May 26, 2021

VIA ELECTRONIC FILING

As described in the Companies' June 6, 2019 Report in this docket, the TSRG webpage, https://www.duke-energy.com/business/products/renewables/generate-your-own/tsrg, provides meeting materials from each prior TSRG meeting, as well as other technical standards documents. The next TSRG meeting is tentatively scheduled for July 21, 2021.

Sincerely,

Rebecca J. Dulin

Attachments

C: Parties of Record (via email w/ attachments)

Interconnection Technical Standards Review Group (TSRG)
Duke Energy Carolinas/Progress
Meeting Agenda
April 28, 2021

In-person meeting converted to web meeting to follow distancing guidelines for COVID-19

9:00	Meeting Administrator remarks
9:02	Safety & Welcome – Wes Davis, Duke
9:05	Review TSRG agenda setting process – Anthony Williams, Duke
9:15	IEEE 1547 implementation plan – Anthony Williams, Duke
9:40	Inspection and commissioning update – Kevin Chen, Duke
10:30	Break
10:45	Second Volt-VAR study report – Anthony Williams, Duke
11:30	Stakeholder feedback on DG Guidance Map – Ryan Boyle, Duke
11:40	Roundtable • Interconnection Portal announcement below • Planned outages update – Wes Davis
11:55	Wrap up & next meeting date – Wes Davis, Duke (Recommend July 21)
12:00	ADJOURN

Duke Energy Interconnection Portal Announcement:

As of April 21, an enhancement has been implemented to increase ACH Payment limit from $100k to $500k per transaction through our Interconnection Portal. This improvement allows larger payment to be submitted through the Interconnection Portal at no additional cost to the customer. We encourage you to use ACH Payment option in lieu of wire transfer because it is less costly to the customers; paperless and secure; better tracking and faster processing.

Duke Energy Carolinas/Progress Interconnection Technical Standards Review Group (TSRG)

Meeting Minutes

April 28, 2021

I. Opening

This is a regular meeting called to order at 9:02 AM. Consistent with COVID restrictions, the meeting was conducted by web conference.

Meeting facilitator: Anthony Williams

Minutes: Anthony Williams

II. Record of Attendance

Member Attendance

Name	Affiliation	Attendance
Kevin Chen	Duke Energy	present
Wes Davis	Duke Energy	present
Jonathan DeMay	Duke Energy	present
Huimin Li	Duke Energy	present
Darren Maness	Duke Energy	present
Orvane Piper	Duke Energy	present
Bill Quaintance	Duke Energy	present
Scott Reynolds	Duke Energy	present
Anthony Williams	Duke Energy	present
Stephen Barkaszi	Duke Energy	present
Ben Brigman	Ecoplexus	present
Paul Brucke	Brucke Engineering	absent
David Brueck	Southern Current	present
Matt Delafield	R-E Services	absent
Jason Epstein	Southern Current	absent
Adam Foodman	O2 Energies EMC	absent
Bruce Fowler	BAM Energy	present
Sean Grier	Duke Energy	absent
Scott Griffith	Duke Energy	present
John Gajda	Strata Solar	present
Chuck Ladd	Ecoplexus	present
Bruce Magruder	BAM Energy	absent
Brad Micallef	Solar Operations Solutions	present
Luke O'Dea	Cypress	absent
Luke Rogers	Birdseye Renewable Energy	absent
Chris Sandifer	SCSBA	present
Michael Wallace	Ecoplexus	present
Mike Whitson	PowerOn Energy	present
John Wilson	Southern Current	absent
James Wolf	Yes Solar Solutions	absent
Jay Lucas	NC Public Staff	absent

Duke Energy Carolinas/Progress Interconnection Technical Standards Review Group (TSRG)

Meeting Minutes

April 28, 2021

Name	Affiliation	Attendance
James McLawhorn	NC Public Staff	absent
Dustin Metz	NC Public Staff	present
Tommy Williamson	NC Public Staff	present
Dawn Hipp	SC Office of Regulatory Staff	absent
Sarah Johnson	SC Office of Regulatory Staff	absent
Robert Lawyer	SC Office of Regulatory Staff	absent
O'Neil Morgan	SC Office of Regulatory Staff	present

Non-member Attendance

Name	Affiliation	Attendance
Wei Ren	EPRI for Duke Energy	present
Greg Ellena	Strata Solar	present
Shawn Fitzpatrick	Advanced Energy	present
Kelsy Green	Advanced Energy	absent
Staci Haggis	Advanced Energy	present
Ken Jennings	Duke Energy	present
Jason Kechijian	Southern Current	present
Mauricio Martinez	Ecoplexus	present
Jim Umbdenstock	Duke Energy	present
Ryan Boyle	Duke Energy	present

III. Current agenda items and discussion

1) The agenda was emailed prior to the meeting.
2) Wes provided the welcome and safety message
3) The antitrust rules were reviewed

4) PRESENTATION: Review TSRG agenda setting process – Anthony Williams, Duke
   A) Presentation will be provided with the meeting minutes
   B) The points on the slide were discussed and the slide serves as documentation of the general process.

5) PRESENTATION: IEEE 1547 implementation plan – Anthony Williams, Duke
   A) Presentation will be provided with the meeting minutes
   B) Industry question – How will the Guidelines be implemented into the interconnection studies?
      (i) Duke response – It will vary across the 1547 topics. Many of the topics are not interconnection related and some are. Others are not new to the standard and already

exist in requirements and in the interconnection process. For the new ones unique to -2018, the impact on interconnection is still to be determined. First, Duke is trying to establish all the requirements for each one in the Guidelines and then we can determine how that impacts both Duke and DER within the interconnection process. There is not a clear answer yet. Also note that there are some requirements, such as abnormal event tripping, that have existed since the first version of 1547. Updating settings for pre-existing functions as part of the -2018 implementation is not applying the new standard to older inverters.

C) Discussion – The effective date will be important for the developers to work with and not be caught off guard
   (i) Duke response – Yes, and the implementation will be discussed in the TSRG just like other items have and be mutually agreed on. The industry can help here by offering when they would like to install a plant with -2018 inverters or when they will actually be able to purchase one. That information will help set the implementation schedule.

D) Industry question – As Duke develops ISOP, how would the new inverter capability be considered, how would it be included in the planning process? How do the calculations include DER?
   (i) Duke response – The TSRG and the Guidelines are more focused on the technical capabilities of the inverters. While someone from ISOP could come in and explain what the plan is within that program; that is more of a policy than technical question. The Guidelines will establish the basis for something like reactive capability: the technical requirements, testing, and interoperability. The Guidelines do not get into how that capability is used or how the inverters are applied.

6) PRESENTATION: Inspection and commissioning update – Kevin Chen, Duke
   A) Presentation will be provided with the meeting minutes
   B) Industry question – What does self-inspection mean with respect to new generation inspections?
      (i) Duke response – Piloting the self-inspection program with TSRG members for older uninspected sites will help everyone understand what a program would or could look like for new sites. This is not a proposal or decision for new sites. Duke believes this program would be beneficial to the DER customers and wants to work collaboratively with stakeholders to define the process.
   C) Industry question – For new facilities, would self-inspection be in lieu of the AE inspection
      (i) Duke response –Self-certification is for inspections and, at this time, not planned for commissioning. Self-inspection is separate from commissioning.
   D) Industry question – Is Duke open to having the Professional Engineer (PE) stamping the inspection be in the owner/operator company?
      (i) Duke response – Yes, that is acceptable. Duke has made this clear in previous meetings that in-house PEs can sign off the self-inspection report of existing uninspected facilities.

As for new facilities, there has been no discussion or decision about who can sign off on those.

E) Industry question – What controls does Duke plan to use for accountability?
   (i) Duke response – The process is built around the honor system. The requirements of the process should help provide assurances of the validity. Also, the PE certification provides validity. Some sites have their own maintenance processes and the thought is this process would add to the existing maintenance practices to make the site more reliable. If excessive failures do occur over time, then Duke has the right to inspect for themselves.

F) Discussion – Could Duke or AE assist on the first inspection at the site?
   (i) Duke response – Duke already makes support available for self-inspection pilots. Duke could also consider making resources available as well.

G) Discussion – One owner noted that a pilot was done at one of their sites and noted that there were concerns identified that were things they would like to improve. The owner encouraged others to participate. Duke also noted benefits as well, such as some streamlining and refinements. The more volunteers, the better the process can become.

H) Industry question – For the inrush test, it seemed like Duke does not have a pass / fail criteria.
   (i) Duke response – The need for mitigation this is identified at the time of the interconnection study and is based on the inrush limit. The current testing process is focused on staggered energization and is a simpler test process. For the other forms of mitigation, there is not currently a test in place. That is what is under development. These new tests require special monitoring to get the voltage and current waveform.

7) PRESENTATION: Second Volt-VAR study report – Anthony Williams, Duke
   A) Presentation will be provided with the meeting minutes
   B) There was no discussion.

8) Stakeholder feedback on DG Guidance Map – Ryan Boyle, Duke
   A) Presentation will be provided with the meeting minutes
   B) There was no discussion.

9) Roundtable
   A) Duke Energy Interconnection Portal Announcement
      (i) As of April 21, an enhancement has been implemented to increase ACH Payment limit from \$100k to \$500k per transaction through our Interconnection Portal. This

improvement allows larger payment to be submitted through the Interconnection Portal at no additional cost to the customer. We encourage you to use ACH Payment option in lieu of wire transfer because it is less costly to the customers; paperless and secure; better tracking and faster processing.

(ii) There was no discussion

B) Planned outages update – Wes Davis

(i) Duke noted that a report is produced each Monday with the status of DER that are out of service. Starting in May, there will be a dedicated resource focusing on DER outages.

(ii) Industry comment – Not everyone at the TSRG is a developer. Some members are focused design, operational, and other aspects and topics that come up in the TSRG. Duke may need to consider how to involve the operations-related people.

10) Wrap up & next meeting date – Wes Davis, Duke

A) Next meeting planned for July 21, 2021

IV. Closing

The meeting concluded at 12:02 PM

V. Attachments

1) Agenda, "TSRG Agenda 2021_0428, Rev 2.pdf"
2) Presentations
   A) Review TSRG agenda setting process, "TSRG Agenda Process.pptx"
   B) IEEE 1547 implementation plan, "TSRG Implement 1547 Update, Apr 28 2021, Rev 0.pdf"
   C) Inspection and commissioning update, "DER commissioning_TSRG_04282021.pdf"
   D) Second Volt-VAR study report, "Volt-VAR study update, 2021-04-28, Rev0.pdf"
3) References
   A) 1547 Guidelines with edits, "Duke Energy IEEE 1547 Implementation Guidelines, Rev 3A"
   B) 1547 Guidelines latest version, "Duke Energy IEEE 1547 Implementation Guidelines, Rev 4"
   C) Comment form, "Duke TSRG Stakeholder Comment Form.xlsx"

Attachment C

TSRG: Inverter Volt-VAR Study Update

Anthony C Williams, DER Technical Standards

April 28, 2021

DUKE ENERGY

Second Study Overview

- More emphasis on higher voltage feeders so that less DER forces the overvoltage
- Calculate P and Q responses
- Consider a broader variety of controller types
  - Limited controller setting variations: approximately 6 volt-var, 8 pf, 5 watt-var
  - Continued use of volt-watt to backup the primary controller
- Expand the attributes monitored during the study; to inform conclusions
- Quasi-Static Time Series (QSTS) simulation using 8760 hourly load and solar profile
- Compare monitored attributes across the feeders for the various controller types
  - Inform policy development to guide application of DER voltage and reactive power controls, and
  - Develop methods to a) provide a quick assessment of reactive power control effectiveness at a potential UDER interconnection point, and b) indicate the most appropriate type of control

General Report Organization

- Introduction
  - Modeling and set up for the study
- Design of reactive power control
  - How the volt-var settings are determined
- Results
  - Review of each feeder
- Conclusions
- Appendix
  - Supplemental PowerPoint files with more results

Summary of Controller Results

- Many observations – final conclusions pending

	Best overall control	Next best VV control	Volt > Limit?	Corrected?
A	VVV3=1.040puslope=2.0%	VVV3=1.026puslope=2.0%zero-OV	yes	no
B	VVV3=1.028puslope=2.0%zero-OV	VVV3=1.046puslope=1.3%zero-DV	yes	yes
C	--	VVV3=1.050puslope=2.0%zero-OV	no	--
D	VVV3=1.040puslope=2.0%	VVV3=1.037puslope=2.0%zero-OV	yes	yes
E	VVV3=1.040puslope=2.0%	VVV3=1.040puslope=2.0%zero-OV	yes	yes
F	VVV3=1.040puslope=2.0%	VVV3=1.033puslope=2.0%zero-OV	yes	yes
G	VVV3=1.026puslope=2.0%zero-OV	VVV3=1.000puslope=3.4%zero-DV	yes	yes
H	WVP2=0%P3=76%Q3=-37%zero-DV	VVV3=1.026puslope=2.0%zero-OV	yes	no
I	--	VVV3=1.050puslope=2.0%zero-OV	no	--
J1	WVP2=0%P3=85%Q3=-37%zero-OV	VVV3=1.026puslope=2.0%zero-OV	yes	no
J2	--	VVV3=1.050puslope=2.0%zero-OV	no	--
K	WVP2=0%P3=85%Q3=-37%zero-OV	VVV3=1.026puslope=2.0%zero-OV	yes	no
L	--	VVV3=1.050puslope=2.0%zero-OV	no	--
M	VVV3=1.040puslope=2.0%	VVV3=1.050puslope=2.0%zero-OV	no	--
N	WVP2=3%P3=100%Q3=-30%zero-DV	VVV3=1.000puslope=6.2%zero-DV	yes	yes

Results

- Reaffirmed real and reactive power injection impacts vary significantly based on the feeder and PCC
- Confirmed various different control options could lead to vastly different levels of reactive power consumption
  - Tuning is important to correct the voltage while not burdening the system with high VARs
  - May result in loss of energy yield when real power generation needs to be traded off for reactive power capability; kVA capability
  - Active power tradeoff is small
- Control options have limited impact on the feeder loss
  - Loss is mainly caused by the real power flow, not the reactive power
- Time Series studies showed
  - Feeder voltage control devices impact optimal reactive power control settings
  - Location of peak voltage varies across the range of DER output and across load level
- More analysis pending; significant amount of data produced;

Conclusions

- dV/dQ is relatively constant; large factor indicates effective voltage regulation
- dV/dP much more likely to have significant variation
- Highest PCC voltage is at maximum Pgen for some- not all; many in the 50-80% range
- Heavily loaded feeders may provide for better control than expected
- Setting methods that include feeder voltage control devices is necessary and provides better voltage management
- For UDER; difficult to apply a universal setting that is effective
  - Effective = prevents overvoltage, minimizes reactive power absorption, no unacceptable regulator tap moves or capacitor switching
- Volt-Var (VV) control: all-around choice
  - responds to voltage / system changes, minimizes reactive power consumption, more complex to set
- Watt-Var (WV) control: VV alternative
  - voltage independent / DER-centric, like PF control but less reactive power consumption

Next Steps

- The simulation results from the study should be examined and considered along with the feeder characteristics to further develop guidance for the application of DER voltage and reactive power controls
  - This could identify next steps
  - Consider how the detailed study results could help identify predictors of effective applications
    - Which locations are definitely effective
    - Which are definitely ineffective
- The Voltage-Real power control would benefit from more work to improve the method of determining settings and making that controller more effective

Attachment C

DUKE ENERGY

BUILDING A ***SMARTER*** *ENERGY FUTURE* SM

Update and Discussion: Action Plan to Implement 1547-2018 TSRG Meeting

Anthony C Williams, P.E.
Principal Engineer

DER Technical Standards

April 28, 2021

DUKE ENERGY

Agenda

- Review main revisions
  - Current version is “Duke Energy IEEE 1547 Implementation Guidelines, Rev 3”
    - Rev 3A is the redline version of Rev 4
- Discussion

Applicability Clarifications

- 1547-2018 will be implemented on inverters certified to UL 1741 SB
- Duke and DER may mutually agree to implement a function in 1547-2018 if there is a comparable IEEE 1547a-2014 function for inverters certified to UL 1741 SA
- no plans to implement the new functions of IEEE 1547-2018 for existing inverters
- Page 7:

~~Prior to requiring IEEE 1547-2018, Duke Energy and the DER Owner for inverters certified to IEEE 1547a-2014 or UL 1741 SA may mutually agree to implement those available functions as needed.~~Duke Energy has no plans to implement the new functions of IEEE 1547-2018 for existing inverters. Not only it is not a common practice at Duke to retroactively apply standards, it is really not even a valid concern because existing inverters do not have many of the 1547-2018 capabilities and are not tested to UL 1741 SB. If a 1547-2018 function is implemented and there is a comparable IEEE 1547a-2014 function for inverters certified to UL 1741 SA, then Duke Energy and the DER Owner may mutually agree to implement those available functions as needed. Similarly, some functions like voltage and frequency tripping have existed throughout all versions of 1547. Revising pre-existing settings is not considered implementation of a new function.¶

DUKE ENERGY

Attachment D

Reactive Capability

- Duke agrees that capabilities 43.6% and higher also meet the intent of the 44%
- Section 5.2:

Category B requires a DER reactive power injection capability (lagging) of 44% of nameplate apparent power rating and 44% absorption capability (leading) of nameplate apparent power rating as defined in the Standard. The Standard adopted "44%" as the injection capability for 0.90 pf, but the percentage is actually slightly less, 43.6%. Duke will consider capabilities 43.6% and higher also meet the intent of the 44% requirement. As a good practice, Duke recommends that all facilities be designed to operate at these pf ratings should the situation arise over the life of the facility that the facility would want this capability. ¶

Commission Presentation

- NC PUC requested an update on the implementation of 1547
- The last report was submittal of the initial Guidelines document April 2020
- Submitted a written update of all related TSRG activities
- Provided a presentation April 12th
  - Will provide with the other TSRG presentations
  - IEEE Standard 1547-2018 overview
  - Topics about the Implementation of IEEE 1547-2018 Guidelines document
  - Standard provisions that may require Commission decisions
  - Stakeholder engagement

Previously Completed Sections

- DUK-13 Section 4.5 – Cease to energize performance requirement
- DUK-27 Section 4.7 – Prioritization Of DER Responses
- DUK-28 Section 4.8 – Isolation device
- DUK-23 Section 4.9 – Inadvertent energization of the Area EPS
- DUK-29 Section 4.11.1 – Protection from electromagnetic interference
- DUK-30 Section 4.11.2 – Surge withstand performance
- DUK-22 Section 4.11.3 – Paralleling device
- DUK-26 Section 4.12 – Integration with Area EPS grounding, ready to be implemented
- DUK-01 Section 5.2 – Reactive power capability of the DER
- DUK-05 Section 7.2.3 – Flicker
- DUK-05 Section 7.3 – Limitation Of Current Distortion

Feedback

- Written feedback and comments will be solicited using comment form
  - Note questions then lets discuss – don't really want all the questions sent in that are mainly just for clarification – this takes a lot of time to address that could be spent on the comments and recommendations
  - It would be helpful to provide both comments and also propose a specific change:

Stakeholder Name	Page Number	Paragraph Number	Comment	Proposed Change
example Question format	3	2	Why is winter data excluded?	None
example Comment format	7	4	Agree with the hours of study.	None
example Comment format	7	4	'the largest' is not clear	Replace 'the largest' with 'the maximum of the three phase currents"
example Recommendation format	10	3	The types of faults is too limited. Include single line to ground faults.	Include SLG faults

  - Suggesting the exact change to the Guidelines reinforces the main point of the comment and provides more information that Duke can specifically address
- Comments will be taken during the meeting and the form will be distributed after the meeting
- Stakeholders may provide written feedback using the feedback form by emailing to: DER-TechnicalStandards@duke-energy.com

Attachment D

Attachment E

DER Commissioning Update

Kevin Chen 4/28/2021

- Self-inspection Update
- Commissioning Test Weather Condition Requirement
- Expected Performance During Commissioning Test
- Inrush Mitigation Device Performance Verification Test
- Load Rejection Overvoltage (LROV) Evaluation
- Q&A, open discussion

Attachment E

Self-inspection Update

- All previously developed self-inspection documents are posted on TSRG website.
- The self-inspection technical training was on 2/11/2021.
  - Link to the video and presentation slides is posted on TSRG website.
  - There were 98 registered participants from 28 organizations.
  - Received messages from 3 companies and 2 individual PE recommending themselves as resources to provide self-inspection service.
- We are working on the self-inspection pilot project, and would like to have more volunteers.
- Duke believes once the self-inspection for previously uninspected sites is proven to be effective, the program could be transitioned to use for new generating facilities.
  - The requirements for new sites will be different from the self-inspection plan being refined for old sites.
- Duke will continue to engage with stakeholders to develop a process that provides flexibility in the interconnection process around inspection and commissioning for Interconnection Customers while ensuring a safe and reliable interconnection to the grid.

Attachment E

Agenda

- Self-inspection Update
- Commissioning Test Weather Condition Requirement
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Attachment E

- Duke Energy PV Interconnection Commissioning Process (Version 7, 8/28/2020)
  - Weather conditions must permit the site to generate at least 20 percent of rated AC current in order to conduct the commissioning tests.

  This requirement was added to the Commissioning Process in version 6, 4/24/2019.

- IEEE 1547.1 – 2005, 5.9.2(c) open phase test procedure

  c) Open one phase conductor disconnect while the EUT is operating at the greater of
  — 5% of rated output current or
  — The EUT's minimum output current.

- IEEE 1547.1 – 2005, 7.5.1(a) cease-to-energize functionality test procedure

  a) Operate the DR interconnected with the area EPS at an output power level available and convenient[38] at the time of testing.

  [38]This test is not intended to be conducted at any specific power level and recognizes that DR output may vary with environmental conditions (e.g., solar photovoltaic, wind, renewable fuels).

- IEEE 1547.1 – 2020, 5.11.2(c) open phase test procedure

  c) Open one phase conductor disconnect while the EUT is operating at the greater of
  1) 5% of rated output current or
  2) The EUT's minimum output current rating.

Attachment E

Minimum Output Current Requirement

- Issues with testing at low output;
  - Current reading at the meter falls within the range of error (a few amperes).
  - Some inverters are not operating or fail to restart.
  - Inverters may have challenge passing the test when operating at extremely low rating.
  - Cause trouble in determining the results and increase the chance of failing the test. Then this may lead to more questions when a re-test is required, especially in the conditional process at end of year.
  - In many cases, it suggests an inconvenient working environment for onsite staff.
- Actions to take:
  - Reaffirm the requirement already defined in the Commissioning Process document.
  - Follow the requirement in practice.

Attachment E

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- IEEE Std 1547 – 2018 defines the following terms:

supplemental DER device: Any equipment that is used to obtain compliance with some or all of the interconnection requirements of this standard.

NOTE—Examples include capacitor banks, STATCOMs, harmonic filters that are not part of a DER unit, protection devices, plant controllers, etc.

DER system	DER system is fully compliant at PCC*—no supplemental DER device needed *Individual DER units that are considered fully compliant at the PoC may only be considered fully compliant at the PCC if the impedance between the PoC and the PCC is less than 0.5% on the DER rated apparent power and voltage base.
Composite	Composite of partially compliant DER that is, as a whole, fully compliant at PCC*—may need one or more supplemental DER device(s). *Individual DER units that are considered fully compliant at the PoC shall not be considered fully compliant at the PCC if the impedance between the PoC and the PCC is equal to or greater than 0.5% on the DER rated apparent power and voltage base.

- One increasingly common “supplemental” device is the customer owned recloser.
- There may be more supplemental devices in future projects to meet IEEE 1547-2018.
- It is critical to ensure the supplemental devices are functioning consistently as designed, as expected, and meeting the requirements.

Attachment E

Test Plan to be Updated

- Test Procedure
  - During the documentation review and site inspection, Duke will work with AE to ask the DER customers to describe the performance (series of actions, functions to provide, or timing, etc.) to be expected in the commissioning test.
- Results Assessment
  - Verify the supplemental devices are functioning consistently as designed, as expected, and meeting the requirements.
- Implementation plan and effective date
  - Duke and AE will start piloting this in Q2, 2021.
  - Duke Energy PV Interconnection Commissioning Process will be updated accordingly in Q3, 2021.
  - The scope of this practice will continue to grow with the IEEE 1547 implementation guideline.

Attachment E

- Self-inspection Update
- Commissioning Test Weather Condition Requirement
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Attachment E

Timeline of Inrush and RVC Limit Requirements

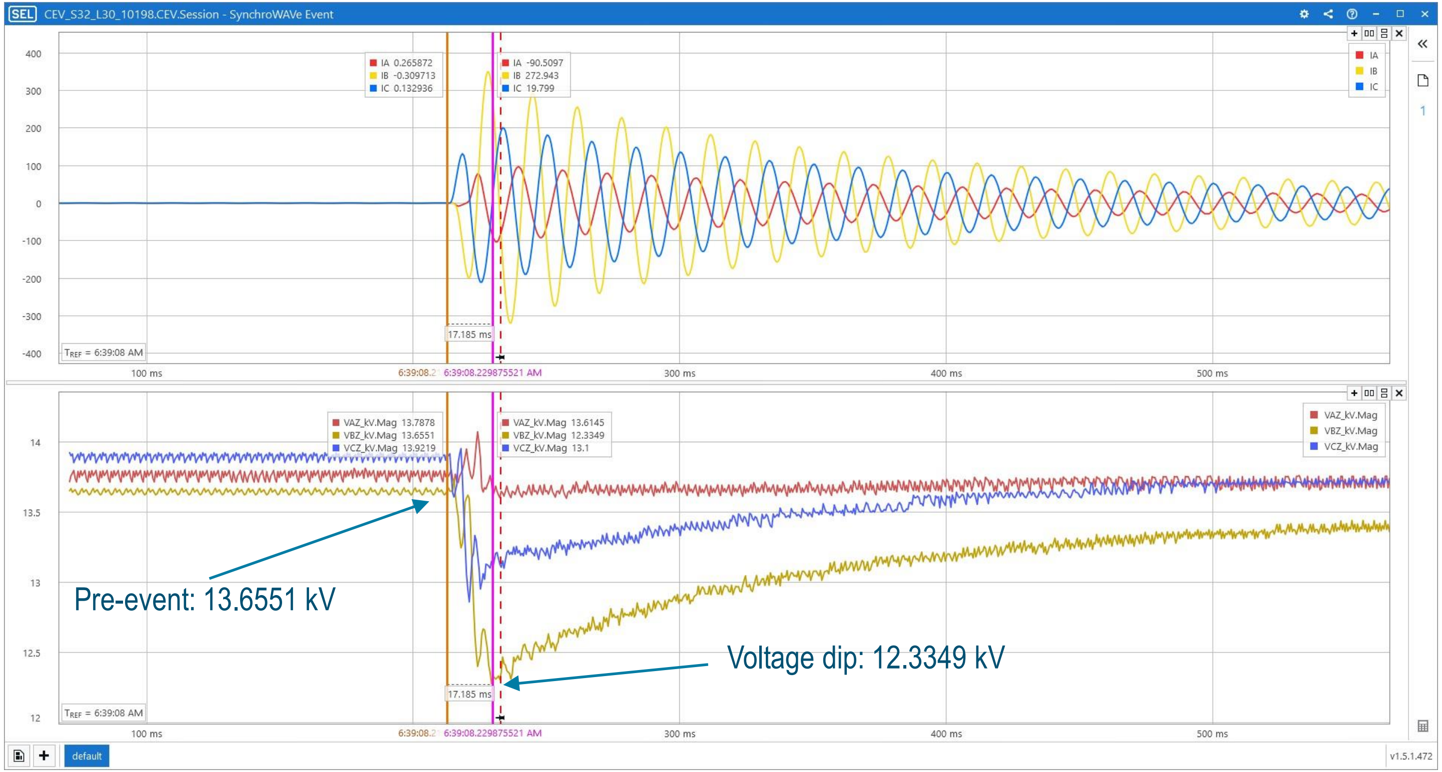
- All transformers inside a DER energized at once => Inrush
- May 2, 2016, recloser connects solar farm to feeder. Extended harmonic distortion impressed upon the substation bus voltage impacts industrial customer on adjacent feeder.
- Duke introduced the “advanced studies” which would evaluate inrush impact, and require mitigation solutions as necessary.
- In 2018, Duke expanded the RVC (rapid voltage change) and flicker study criteria to include transformer energization inrush and solutions.
- Limits to Voltage Disturbances Due to Inrush – 10/22/2018 TSRG meeting
- Transformer Energization RVC Limit – 1/23/2019 TSRG meeting
- Sequential Switching Requirements – 9/17/2019 TSRG meeting

Attachment E

- Potential solutions at customer's choice:
  - Staggered energization of transformer blocks
  - Controlled switching device (CSD) or similar point on the wave switching equipment
  - Pre-insertion resistor
  - Pre-insertion back to back transformers
  - Pre-energization transformer secondary
- If a DER project is equipped with staggered energization scheme, or any other in-rush mitigation options, AE will review the documentation to make sure such option has been reflected in the design prior to site inspection.
- During the inspection, AE will inspect the installation of relevant components of the in-rush mitigation for any safety and reliability risk. When applicable, the DER may demonstrate the operation of in-rush mitigation system using portable generator.
- At the commissioning test, AE will observe the staggered energization system operation to ensure the switching sequence and time delay meet Duke's requirements and customer's design.
- The gap in current process is that no measurement or recording of voltage or current being reviewed to evaluate the effectiveness of the in-rush mitigation.

Attachment E

Inrush Event Measured at Recloser



$\Delta V\% = 9.67\%$

Attachment E

Test Plan to be Considered

- Test Procedure

  1. Disconnect customer owned switch while Duke's recloser is in close position. The whole site will be de-energized but Duke's recloser is still closed.
  2. Close the customer owned switch to initiate DER site energization sequence.
  3. Repeat above steps twice to get 3 total tests.
  4. Collect any event file saved by Duke's recloser from above tests. And examine the waveform of current and voltage to pass/fail the test results.

- Results Assessment
  - Need to obtain and review the voltage and current waveforms captured during the test.
- Implementation plan and effective date
  - Need to pilot the test plan
  - Effective date is to be further determined, can be as soon as Q3, 2021.

Attachment E

- Self-inspection Update
- Commissioning Test Weather Condition Requirement
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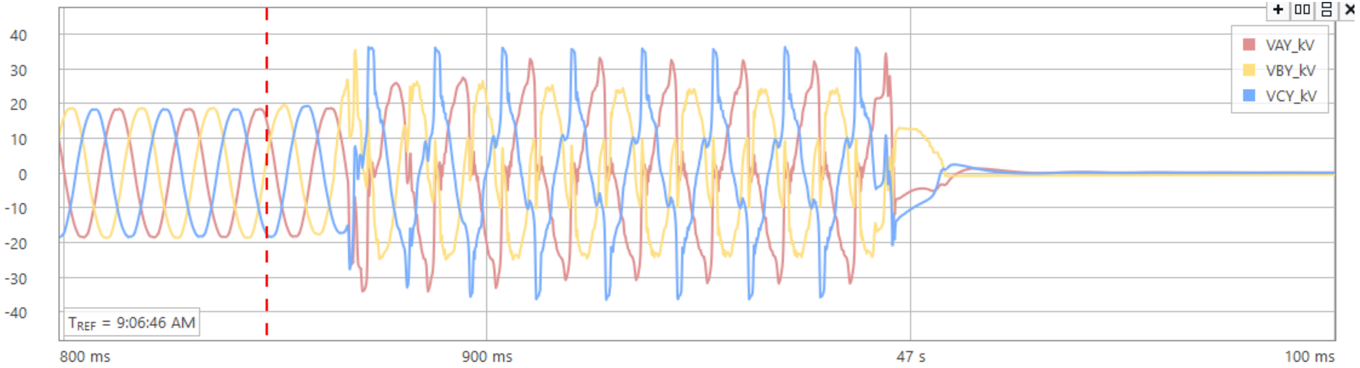
Attachment E

- Load rejection overvoltage can be measured when the recloser opens while solar farm is generating.



- Many cases of arresters, PTs being damaged by such overvoltage. (Utility's meter pole or customer's pole)
  - Cause event to distribution system
  - Interrupt energy production
  - Extra workload to field meter tech
  - Lead to discussion of ***where the utility revenue meter should be located***: trade off between more often meter PT damage and low probably high consequence of feeder lockout.

Attachment E

- IEEE Std 1547 – 2018, 7.4.2 Limitation of cumulative instantaneous overvoltage

  The DER shall not cause the instantaneous voltage on any portion of the Area EPS to exceed the magnitudes and cumulative durations shown in Figure 3.

- Other utility’s practice, Georgia Power – Southern Company

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Load Rejection Transient Overvoltage

- DERs are not supposed to produce over voltages temporary or otherwise above 2.0 pu.
- Most inverter based DERs produce above 2.0 pu when the load rejection happens at the Point of Common Coupling (PCC).
- If the load rejection happens three or four devices upstream of the DER, all the customers between the DER and the open device will be subject to this TOV.
- LROV test is to check the level of potential overvoltage produced by DERs when a load rejection occurs due to opening of a three-phase disconnecting device anywhere on the feeder.

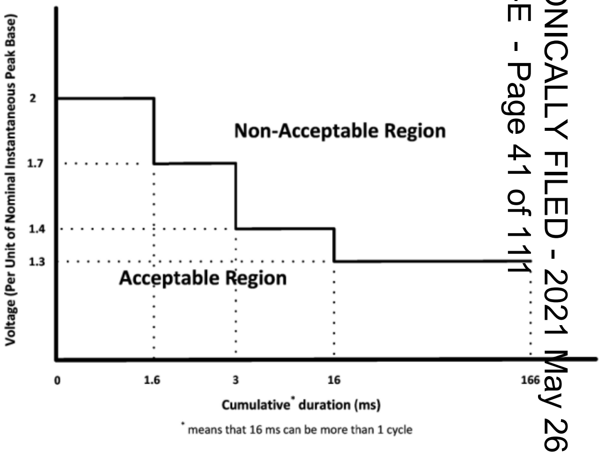
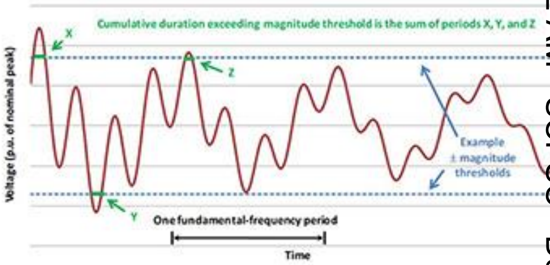


Figure 3 —Transient overvoltage limits



Attachment E

Test Plan to be Considered

- Test Procedure
  - Three-phase disconnection is already part of the cease-to-energize test, no extra test action is required.
- Results Assessment
  - Need to obtain and review the voltage waveform captured during the test.
- Implementation plan and effective date
  - This will continue to be part of the IEEE 1547 implementation guideline.
  - Need to pilot the test plan
  - Effective date is to be further determined, can be as soon as Q3, 2021.

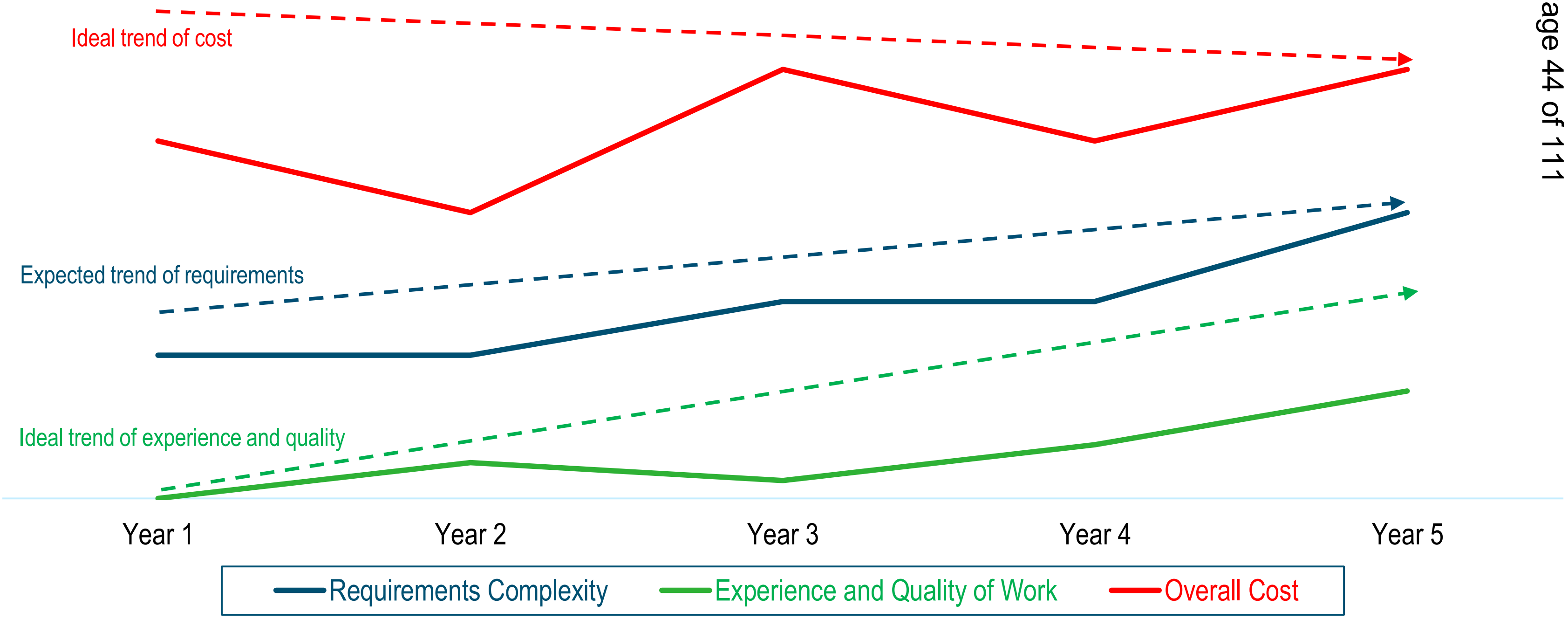
Attachment E

- Self-inspection Update
- Commissioning Test Weather Condition Requirement
- Expected Performance During Commissioning Test
- Inrush Mitigation Device Performance Verification Test
- Load Rejection Overvoltage (LROV) Evaluation
- Q&A, open discussion

Attachment E

Factors Impact the Trend

Chart is for illustration purposes only, not to scale or quantify.



New standards / requirements: ↑↓↑ New devices / technology: ↑↓↑ Operational issues: ↑↓↑ New staffing: →↓↑

Attachment E

Attachment E

Implementation of IEEE 1547-2018 Guidelines for Duke Energy Carolinas and Duke Energy Progress

Duke Energy

Duke Energy Carolinas and Duke Energy Progress

Distributed Energy Technology

DER Technical Standards

Revision 3A

April 28, 2021

Implementation of IEEE 1547-2018 Guidelines for Duke Energy Carolinas and Duke Energy Progress

Revision	Date	Description
0	3/31/2020	Initial issue
1	7/21/2020	General update prior to July 2020 TSRG meeting
2	10/28/2020	General update prior to Oct. 2020 TSRG meeting
3	1/20/2021	General update prior to Jan. 2021 TSRG meeting
4	4/28/2021	General update prior to Apr. 2021 TSRG meeting

CONTENTS

INTRODUCTION

Duke Energy seeks to implement smart inverter technical specifications and requirements as defined in the updated IEEE Standard 1547-2018, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems (IEEE 1547 or the Standard). This document focuses only on the distributed energy resources (DER) connected to the distribution system and not those connected to the transmission or bulk power system (BPS). In North and South Carolina, the implementation of IEEE 1547 is focused on large utility scale DER (UDER) because there had been significant number of those installations. Some of IEEE 1547 requirements are also applicable to the smaller retail and residential DER (RDER). If there are any variations in application of the Standard to UDER and RDER, those conditions will be noted in this document.

Note to the format of this document. This guideline is meant to be a living document. For now, it captures where Duke Energy is in the process of implementing IEEE 1547-2018. This document notes sections of the standard that require no additional analysis or review and those that are under review and those that must still be reviewed. In sections highlighted like this paragraph, there will be a brief discussion of the ongoing work to be concluded to address implementation of that Standard section.

The standard is an inverter Standard and not a utility standard, therefore many parts of the Standard can be implemented by Duke Energy simply by adopting IEEE 1547-2018 as the applicable standard for Duke Energy inverter based interconnections. However, there are some sections of the Standard that require input or specifications from the utility. The Standard specifies inverter capabilities and functions, but not utilization. The purpose of this document is to clarify any additional information for utilization.

The standard is applicable to DER connected at the primary or secondary distribution system voltage levels. However, some of the Standard requirements are based on conditions and issues related to the BES. There can be situations where the aggregate distribution DER capacities are large enough to impact the NERC BES reliability. In those cases, BES requirements are implemented in DER connected to the distribution system. However, these requirements are not directly distribution requirements, but BES requirements applied at the distribution power system level. The interaction between the BES and the distribution system is well covered in the NERC Reliability Guideline: Bulk Power System Reliability Perspectives on the Adoption of IEEE 1547-2018. The guideline recommends that the BPS entities (BA, RC, PC, TP) coordinate with the Distribution Providers (DP) to achieve successful implementation of the Standard.

This Duke Energy Guideline is applicable to DER located in the Duke Energy service territories in North Carolina and South Carolina. The Guidelines have been developed based on input and comments from TSRG stakeholders.

CONSIDERATION OF IEEE 1547 SECTIONS THAT COULD INCREASE INTERCONNECTION CAPABILITY

The following IEEE 1547 controls or functions are the primary functions that could potentially increase the amount of DER capacity (higher penetration) that can interconnect with minimal feeder upgrades:

i) 4.6.2 Capability to limit active power
ii) 5.3 Voltage and reactive power control
iii) 5.4 Voltage and active power control

While power quality issues can still restrict interconnection, the voltage and reactive power controls are a potential mitigation to those issues too.

While there are other inverter functions that improve reliability of the interconnection, the inverter functions listed above would be the primary drivers for adding more DER capacity to a feeder. Therefore, these functions were assigned a higher priority to review and analyze.

CONSIDERATION OF IEEE 1547 SECTIONS THAT IMPACT GRID SUPPORT

In addition to prioritizing assessment of those sections of IEEE-1547 that could increase interconnection capability, the Companies are also prioritizing those sections that could impact grid support. The 2003 version of the standard created reliability concerns by not providing voltage regulating capability and tripping for abnormal system conditions. While the 2014 version addressed some of the grid reliability concerns, 2018 provides even more inverter capabilities. Also, documents such as the NERC Reliability Guideline: Bulk Power System Reliability Perspectives on the Adoption of IEEE 1547-2018 focus "on ensuring reliable operation of the BPS under increasing penetrations of BPS-connected inverter-based resources as well as distributed energy resources (DERs)." One objective of such documents is to encourage timely adoption of the IEEE 1547-2018 that are likely to impact or support the BPS.

The priority of review of the Standard sections identified in the table is consistent with this industry guidance in that many of the first and second priority selected topics were noted in the NERC guideline as well. Sections 4.2 and 4.10.2 are fourth priority for Duke, but that is mainly because these topics are thought to be more straightforward to address and will likely not require significant evaluation. Interoperability was noted by NERC and Duke plans to address that on a topic by topic basis rather than as one stand-alone interoperability topic. In this way, interoperability is addressed concurrent with the technical considerations for each topic.

The following topics are yet unranked by Duke, but they are in the NERC guideline: 6.4.2.7, 6.5.2.8, 8.1, 8.2. Section 6.4.2.7 was added to the Duke list after the NERC guideline review. These were not ranked during the Duke process because of the lower priority placed on them by the TSRG stakeholders and Duke. These are also topics that need more time and investigation by the industry, so addressing some of the better understood and higher prioritized items first is a reasonable path forward.

PRIORITY OF IMPLEMENTING THE IEEE 1547 TECHNICAL SPECIFICATIONS AND REQUIREMENTS

There are many aspects of implementing the Standard that must be considered. The technical specifications and requirements must be understood and assessed to determine if there is a need to clarify any technical points for consistent application across the Duke system. Duke subject matter experts, TSRG stakeholders, NC Public Staff, and industry documents were included in the activity to set priority for the various Standard sections. The areas of the Standard that stand out as most important are the ride through capability and voltage and reactive power controls.

Below is the priority order at this time considering all TSRG input. If there is no priority stated in the list, then the priority of those items is yet to be assigned. Note that the priority group and the assigned Duke identification number[1] for that item are both in the first column. The remaining IEEE 1547-2018 clauses and sections that do not have a priority assigned will be undertaken following the completion of the higher priority topics. The three columns on the far right side of the table summarize the status for the technical, interoperability, and verification and test aspects for each Standard topic. Many of the summaries are not the final decision because the topic requires more analysis and assessment. However, this table still provides a general overview.

[1] Only the prioritized Duke identification numbers represent the sequence of evaluation, and are numbered less than 100. Numbers greater than 100 are temporarily assigned to the topic until that topic is given a specific priority.

Duke Energy Selected Order of Precedence for IEEE 1547 Sections

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
1 (DUK-01)	5.2	Reactive power capability of the DER	Category B ~~35° C ambient or higher at rated voltage~~	No Reqmt	Eval + Comm Test
1 (DUK-02)	5.3	Voltage and reactive power control	Study in progress	Yes	Eval + Comm Test
1 (DUK-03)	5.4.2	Voltage-active power control	Study in progress	Yes	Eval + Comm Test
1 (DUK-04)	7.4	Limitation of overvoltage contribution	Accept 1547 with additional requirements	No Reqmt	Eval + Comm Test
1 (DUK-05)	7.2.3	Power Quality, Flicker	Accept 1547 in conjunction with continued use of IEEE 1453	No Reqmt	Eval + Comm Test
1 (DUK-06)	7.2.2	Power Quality, Rapid voltage change (RVC)	Continue existing criteria and policy	TBD	TBD, Eval + Comm Test
2 (DUK-07)	6.4.1	Mandatory voltage tripping requirements (OV/UV)	Have existing setpoints; new 1547 setpoint study in progress	TBD	Eval + Comm Test
2 (DUK-08)	6.5.1	Mandatory frequency tripping requirements (OF/UF)	Have existing setpoints; new 1547 setpoint study in progress	TBD	Eval + Comm Test
2 (DUK-09)	6.4.2	Voltage disturbance ride-through requirements	Study in progress	TBD	Eval + Comm Test
2 (DUK-10)	6.5.2	Frequency disturbance ride-through requirements	Study in progress	TBD	TBD, Eval + Comm Test
2 (DUK-11)	6.5.2.7	Frequency-droop (frequency-power) capability	Evaluation has not begun	No Reqmt	TBD, Eval + Comm Test
2 (DUK-12)	6.5.2.6	Voltage phase angle changes ride-through	Study in progress	No Reqmt	TBD, Eval + Comm Test
3 (DUK-13)	4.5	Cease to energize performance requirement	Accept 1547 as written	No Reqmt	Eval + Comm Test
3 (DUK-14)	4.6.1	Capability to disable permit service	Accept 1547 as written	Yes	TBD, Eval + Comm Test
3 (DUK-15)	4.6.2	Capability to limit active power	Accept 1547 as written	Yes	TBD, Eval + Comm Test
4 (DUK-16)	6.5.2.5	Rate of change of frequency (ROCOF)	Study in progress	TBD	TBD, Eval + Comm Test

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
4 (DUK-17)	4.2	Reference points of applicability (RPA)	Accept 1547 as written; consider clarifications	No Reqmt	TBD, Eval.
4 (DUK-18)	4.3	Applicable voltages	Accept 1547 as written; consider clarifications	Yes	TBD, Eval.
4 (DUK-19)	4.10.2	Enter service criteria // 6.6 Return to service after trip	Accept 1547 as written; consider clarifications	TBD, Yes	TBD, Eval + Comm Test
4 (DUK-20)	4.10.3	Performance during entering service	Accept 1547 as written; consider clarifications	TBD, Yes	Eval + Comm Test
4 (DUK-21)	4.10.4	Synchronization	Accept 1547 as written; consider clarifications	No Reqmt	TBD, Eval + Comm Test
4 (DUK-22)	4.11.3	Paralleling device	Accept 1547 as written	No Reqmt	Type Test
5 (DUK-23)	4.9	Inadvertent energization of the Area EPS	Accept 1547 as written	No Reqmt	Eval + Comm Test
5 (DUK-24)	6.3	Area EPS reclosing coordination	Accept 1547 as written; consider clarifications; part of ongoing study	No Reqmt	Eval.
5 (DUK-25)	6.2	Area EPS faults and open phase conditions	Accept 1547 as written; consider clarifications; part of ongoing study	TBD	Eval + Comm Test
5 (DUK-26)	4.12	Integration with Area EPS grounding	Accept 1547 with clarifications	No Reqmt	Eval.
5 (DUK-27)	4.7	Prioritization of DER responses	Accept 1547 as written	No Reqmt	TBD, Eval + Comm Test
5 (DUK-28)	4.8	Isolation device	Accept 1547 as written	No Reqmt	Eval + Comm Test
5 (DUK-29)	4.11.1	Protection from electromagnetic interference	Accept 1547 as written	No Reqmt	Type Test
5 (DUK-30)	4.11.2	Surge withstand performance	Accept 1547 as written	No Reqmt	Type Test
5 (DUK-31)	4.6.3	Execution of mode or parameter changes	Accept 1547 as written	TBD, Yes	TBD, Eval + Comm Test
- (DUK-101)	9	Secondary network	Duke does not currently have these	No Reqmt	-
- (DUK-102)	11.4	Fault current characterization	TBD	No Reqmt	-

Attachment F

DUKE ENERGY

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
- (DUK-103)	8.1	Unintentional islanding	TBD	Yes	-
- (DUK-104)	8.2	Intentional islanding	TBD	Yes	-
- (DUK-105)	11	Test and verification	TBD	-	-
- (DUK-106)	10.2	Monitoring, control, and information exchange requirements	TBD	Yes	-
- (DUK-107)	10.5	Monitoring information	TBD	Yes	-
- (DUK-108)	6.4.2.5	Ride-through of consecutive voltage disturbances	TBD	No Reqmt	-
- (DUK-109)	6.4.2.6	Dynamic voltage support	TBD	No Reqmt	-
- (DUK-110)	6.5.2.8	Inertial response	TBD	No Reqmt	-
- (DUK-111)	10.1	Interoperability requirements	TBD	Yes	-
- (DUK-112)	10.3	Nameplate Information	TBD	Yes	-
- (DUK-113)	10.4	Configuration information	TBD	Yes	-
- (DUK-114)	10.6	Management information	TBD	Yes	-
- (DUK-115)	10.7	Communication protocol requirements	TBD	Yes	-
- (DUK-116)	10.8	Communication performance requirements	TBD	Yes	-
- (DUK-117)	10.9	Cyber security requirements	TBD	Yes	-
- (DUK-118)	7.3	Limitation of current distortion	TBD	TBD	-
- (DUK-119)	4.13	Exemptions for Emergency Systems and Standby DER	TBD	TBD	-
- (DUK-120)	6.4.2.7	Restore output with voltage ride-through	TBD	No Reqmt	0

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LOGISTICS OF IMPLEMENTING OF IEEE 1547-2018

After the technical aspects of each Standard section are understood, Duke Energy can then determine the necessary changes to implement that section. This could vary from taking no action, to updating documentation, to changing work, study, and operational practices. Additionally, a consequence of more inverter functions will be the necessary increase in interoperability requirements as well as DER equipment and DER system verification and testing to confirm design and functional requirements. There are many aspects to consider before implementing each 1547 section. Because the actions to implement each section can vary widely, the implementation will be addressed in each section rather than as a whole for the entire Standard.

It is understood that many of the functions will not be available until IEEE 1547-2018 certified inverters are tested and available to the market. At that time, Duke Energy shall require all inverters to be IEEE 1547-2018 certified. All functions and requirements may not be applicable or implemented at the time the inverters become certified or that Duke Energy requires the certification.

~~Prior to requiring IEEE 1547-2018, Duke Energy and the DER Owner for inverters certified to IEEE 1547a-2014 or UL 1741 SA may mutually agree to implement those available functions as needed.~~Duke Energy has no plans to implement the new functions of IEEE 1547-2018 for existing inverters. Not only it is not a common practice at Duke to retroactively apply standards, it is really not even a valid concern because existing inverters do not have many of the 1547-2018 capabilities and are not tested to UL 1741 SB. If a 1547-2018 function is implemented and there is a comparable IEEE 1547a-2014 function for inverters certified to UL 1741 SA, then Duke Energy and the DER Owner may mutually agree to implement those available functions as needed. Similarly, some functions like voltage and frequency tripping have existed throughout all versions of 1547. Revising pre-existing settings is not considered implementation of a new function.

PLANT REQUIREMENTS

Guidelines must consider how all sections may apply if implemented on a plant-scale with a power plant controller rather than at the individual inverter units. There may need to be some tests for verification that the plant controller performs the intended functions and that the underlying inverters to not behave contrary to the plant controller configuration or commands.

Note that in the following part of this document, the title of each section is the IEEE 1547-2018 section or subsection number and title.

SECTION 1.4 – GENERAL REMARKS AND LIMITATIONS

Duke Energy accepts the scope of the Standard as specified in this section. For UDER, the single point of common coupling (PCC) is located at the boundary between the utility electric power system (EPS) and the local EPS or DER EPS.

The technical specifications and requirements for some performance categories are specified by general technology-neutral categories. For categories related to reactive power capability and voltage regulation performance requirements, Duke Energy requires the following normal performance category:

Voltage and Reactive Power Category B

For categories related to response to Area EPS abnormal conditions, Duke Energy requires the following abnormal operating performance categories:

Synchronous generation	Category I
Induction generation	Mutual agreement
Inverter-based generation	Category III*
Inverter-based storage	Category III*

This section shall be applicable once 1547-2018 inverters are certified and required or if by mutual agreement between Duke Energy and the DER Owner for inverters certified to IEEE 1547a-2014 or UL 1741 SA.

* Final determination for the Category has not been made. More analysis is required and included as part of a study conducted jointly between the Duke Protection and Transmission Planning groups. This work includes a significant effort to model the system, perform iterative studies, and perform research. The main focus is on Category II and that is expected to be the minimum requirement for IBR. With the amendment to IEEE 1547a-2020 approved and many utilities standardizing on Category III, that is the most likely selection.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Independent laboratory certifications that attest to the normal and abnormal categories shall satisfy verification for this requirement.

Implementation of this section requires publishing the final position and integrating verification requirements into the overall commissioning test program.

SECTION 4.2 – REFERENCE POINTS OF APPLICABILITY (RPA)

Duke Energy requires the RPA for all performance requirements for UDER to be the PCC (point of common coupling), which is also known as the point of delivery or change of ownership point on the medium voltage side of the DER transformer(s). The RPA for net meter installations is the PoC (point of connection) at the inverter terminals.

Pending analysis: The expectation is that Duke can accept the Standard as written, but Duke must still determine if there are any applicable exceptions or clarifications needed given this portion of section 4.2:

> Alternatively, for Local EPSs where zero sequence continuity[27] between the PCC and PoC is maintained and either of the following conditions apply, the RPA for performance requirements of this standard may be the *point of DER connection* (PoC), or by mutual agreement between the *Area EPS* operator and the *DER operator*, at any point between, or including, the PoC and PCC:
>
> a) Aggregate DER nameplate rating of equal to or less than 500 kVA, *or*
>
> b) Annual average load demand[28] of greater than 10% of the aggregate DER nameplate rating, and where the Local EPS is not capable of, or is prevented from, exporting more than 500 kVA for longer than 30 s.
>
> For all other Local EPSs meeting either of the conditions a) or b) above but not meeting the requirement for zero sequence continuity, the RPA for performance requirements other than the response to *Area EPS* abnormal conditions specified in 6.2 and 6.4 shall be the PoC, or by mutual agreement between the *Area EPS operator* and the *DER operator*, at any point between, or including, the PoC and PCC. The RPA for performance requirements of 6.2 and 6.4 shall be a point between, or including, the PoC and PCC that is appropriate to detect the abnormal voltage conditions.[29, 30]
>
> Where the RPA is not at the PCC, any equipment or devices in the Local EPS between the RPA and the PCC shall not preclude the DER from meeting the disturbance ride-through requirements specified in 6.4.2 and 6.5.2.[31]
>
> For Local EPS where aggregate DER nameplate rating is greater than 500 kVA, and annual average load demand[28] is greater than 10% of the aggregate DER nameplate rating, and the Local EPS is capable of, and is not prevented from, exporting more than 500 kVA for longer than 30 s, the RPA shall be the PCC and

The final position must consider the variety of RDER and UDER interconnections and identify the RPA for each. In practice, the interconnections have been very straightforward. The default RPA is the PCC. Zero sequence continuity is not a factor for UDER, so the RPA for UDER is the PCC (point of common coupling at the utility interconnection point). The RPA for net meter installations must consider a variety of conditions, as noted in the decision trees, H.1 and H.2. Note that Section 4.12 also addresses grounding and zero sequence continuity.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke will to review DER design documents to confirm the location of the RPA is correct.

Implementation of this section requires publishing the final technical position.

SECTION 4.3 – APPLICABLE VOLTAGES

Duke Energy will consider if there is a need to clarify any technical points for the final version of the guideline, but the expectation is that the section is implemented as written. The expected outcome is that

RDER parameters shall be monitored at the inverter terminals and UDER parameters shall be monitored at the EPS voltage level and used for inverter functions.

Interoperability requirements: Applicable voltages are provided to the local DER interface with Duke Energy.

Verification and test requirements: To be determined.

The applicable voltage should be identified in the interconnection process. Duke plans to review design document to verify the DER meet this requirement.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface, and integrating verification requirements into the overall commissioning test program.

SECTION 4.5 – CEASE TO ENERGIZE PERFORMANCE REQUIREMENT

Duke Energy requires cease to energize capability (not delivering power during steady-state or transient conditions) in accordance with the Standard.

A DER can be directed to cease to energize and trip by changing the Permit service setting to “disabled” as described in IEEE 1547 subsection 4.10.3.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review design document and equipment specification to identify the interconnection device that provides the cease-to-energize function. The existing inspection and commissioning process tests to verify the device meets the performance requirement.

This section is ready to be implemented.

SECTION 4.6 – CONTROL CAPABILITY REQUIREMENTS

Duke Energy will consider if there is a need to clarify any technical points for the final version of the guideline, but the expectation is that the capabilities in the following sections will be adopted as written.

Duke accepts the capabilities in the following sections as written:

- 4.6.1 Capability to disable permit service
- 4.6.2 Capability to limit active power
- 4.6.3 Execution of mode or parameter changes

This section of the Standard applies to all DER 250 kW or greater or DER with a local DER communication interface.

For UDER, Duke Energy is still considering implementing the permit service at the inverter or disconnecting at the local EPS.

Application to RDER has not been assessed.

Note that 4.6.2 is essentially part of the system impact study (SIS) process now because the maximum active power capacity (import or export) is often calculated during the SIS if the requested DER capacity is not possible without upgrades. The Standard defines the active power limit as a percentage of the Nameplate Active Power Rating. Duke interprets the referenced rating as the Nameplate Active Power Rating at unity power factor. Consider too that the active power limit is manually set and Duke does not have the capabilities to adjust the limit based on time of day, load, or other variables.

Duke does not plan to implement real-time control during the initial implementation of the Standard. Significant technical studies are required to address concerns and consider remote real-time control of the active power limit. However, it is reasonable to make provision for this potential capability when designing the monitoring and control capabilities of the communication interface.

Interoperability requirements: The present automation controller implementation uses an Analog Output sent via SCADA to control active power.

Verification and test requirements: Duke will review UL certification tests, type tests, design documents, and equipment specifications to identify the capability of the DER to meet this performance requirement. Duke's current policy requires a utility owned interconnection recloser for UDER >= 1MW. In this case the permit service is implemented by controlling the utility owned recloser. For DER >= 250kW and <1MW, Duke allows the option of installing the small DG interface instead of the utility owned recloser. In this case, the permit service is implemented at the DER unit through the small DG interface.

Implementation of this section requires publishing the final technical position.

SECTION 4.7 – PRIORITIZATION OF DER RESPONSES

Duke Energy expects IEEE 1547-2018 compliant inverters to meet all prioritization requirements of this section of the Standard.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review UL certification testing, type tests results, and design documents to evaluate if a DER can meet this requirement.

This section is ready to be implemented.

SECTION 4.8 – ISOLATION DEVICE

Duke Energy requires isolation devices per the Interconnection Agreement, Method of Service Guidelines, and other interconnection documents. This is a current requirement that is unchanged by IEEE 1547-2018.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Existing site evaluation and inspection shall satisfy verification for this requirement.

This section is ready to be implemented.

SECTION 4.9 – INADVERTENT ENERGIZATION OF THE AREA EPS

Duke Energy requires DER not to energize the utility EPS when the utility EPS is de-energized. When there is a planned and designed intentional island, per Section 8.2 Intentional Islanding, that configuration is not considered inadvertent.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke will only accept type-tested DER for small scale installations like RDER. For UDER, the existing inspection and commissioning process covers this requirement.

This section is ready to be implemented.

SECTION 4.10 – ENTER SERVICE

Duke Energy requires the DER to meet the requirements of all the following subsections:

- 4.10.2 Enter service criteria
- 4.10.3 Performance during entering service
- 4.10.4 Synchronization

> Duke must still determine the enter service criteria and enter service time delays. Note that while the Standard mentions Range B of ANSI C84.1, that voltage is at the service level (low side of the service transformer) and not at the primary side. Therefore, the settings in the Standard would be more relevant to RDER than UDER that has the RPA and PCC at the primary side of the DER transformer. The RDER values are common in the industry and are Standard defaults.

When entering service, the DER shall not energize the Area EPS until the following conditions are met:

Enter service value	**Parameter Label**	**RDER setting (Service tx sec)**	**UDER setting (DER tx pri)**

Minimum Voltage	ES_V_LOW	≥ 0.917 p.u.	≥ p.u.
Maximum Voltage	ES_V_HIGH	≤ 1.05 p.u.	≤ p.u.
Minimum Frequency	ES_F_LOW	≥ 59.5 p.u.	≥ p.u.
Maximum Frequency	ES_F_HIGH	≤ 60.1 p.u.	≤ p.u.

Note: The parameter labels are based on the publicly available EPRI technical update document number 3002020201, "*Common File Format for Distributed Energy Resources Settings Exchange and Storage.*"

The final UDER settings are still under evaluation. Duke will compare the final voltage trip and ride through settings for UDER with the Standard default settings. Assuming they are compatible, UDER will adopt the same Standard default values.

The DER shall not enter service or ramp faster than the times stated below. A randomized time delay is optional and not currently used within the Duke system. As noted in the standard, DER increasing active power steps greater than 20% of Nameplate Active Power rating shall require approval during the system interconnection study process.

Time Delay	**Parameter Label**	**RDER setting (seconds)**	**UDER setting (seconds)**
Enter Service Delay	ES_DELAY	300	300
Enter Service Ramp Period	ES_RAMP_RATE	300	300
Enter service randomized delay	ES_RANDOMIZED_DELAY	Off	Off

While the active power is ramping during the enter service period, the reactive power shall follow the configured mode and settings.

When connected in parallel with the Area EPS, energy storage DER (ESS) active power rate of change is dependent on the Configuration Active Power Rating per the table below:

Rate of Change Duration	**Parameter Label**		**RDER setting (seconds)**	**UDER setting (seconds)**
ESS ≤ 1 MW	None		2	n/a
ESS > 1 MW	None		n/a	ESS MW rating / (2 MW/sec)

Interoperability requirements: To be determined.

Duke will evaluate if there is value in monitoring the enter service settings.

Verification and test requirements: For 4.10.2 and 4.10.3, Duke plans to verify the enter service and return to service settings in the field. The existing inspection and commissioning process tests to verify DER meets this requirement. For 4.10.4, Duke plans to review UL certification tests, type tests, and design documents to evaluate DER's synchronization capability meeting this requirement. The on-off test during commissioning will field verify DER's synchronization capability.

Implementation of this section requires publishing the final technical position and applying the interoperability functionality in the local interface.

SECTION 4.11 – INTERCONNECT INTEGRITY

Duke Energy requires the DER to meet the requirements of all the following subsections:

4.11.1 Protection from electromagnetic interference
4.11.2 Surge withstand performance
4.11.3 Paralleling device

Duke Energy does not have additional clarifications of these subsections.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: They standard type-testing is satisfactory for Duke.

This section is ready to be implemented.

SECTION 4.12 – INTEGRATION WITH AREA EPS GROUNDING

Duke accepts the Standard; that the grounding scheme of the DER interconnection shall be coordinated with the ground fault protection of the Area EPS. Duke's system is multi-grounded and the DER facilities and design must be compatible with the EPS. Each interconnection is reviewed for ground fault protection and for limiting the potential for creating over-voltages on the Area EPS.

Approved distribution connected utility scale DER transformer winding configurations are listed below. Therefore, configurations that are not listed are not approved. It is possible for an IC to submit another winding configuration, however the technical review will significantly delay evaluation of the IR.

Primary Winding Type (HV)	**Secondary Winding Type (LV)**	**Zero Seq Maintained PCC to POC**	**Allowed for DER Interconnection**	
			Inverter	**Rotating**
Wye-grounded	Wye-grounded	Yes, (w/4-wire LV)	Yes	Yes
Wye-grounded	Wye	No	Yes	No
Wye-grounded	Delta	No	No	Yes

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review the design document to evaluate if a DER can meets this requirement. The existing inspection and commissioning test process will cover this.

This section is ready to be implemented.

SECTION 5.2 – REACTIVE POWER CAPABILITY OF THE DER

Whether or not reactive power capability or voltage control is initially used for the DER, each DER shall submit the required reactive power capability information. This provides the information when it is most readily available and can be recorded in the event that it is needed later.

For categories related to reactive power capability and voltage regulation performance requirements, Duke Energy plans to require the following performance category:

Voltage and Reactive Power Category B

Category B requires a DER reactive power injection capability (lagging) of 44% of nameplate apparent power rating and 44% absorption capability (leading) of nameplate apparent power rating as defined in the Standard. The Standard adopted "44%" as the injection capability for 0.90 pf, but the percentage is actually slightly less, 43.6%. Duke will consider capabilities 43.6% and higher also meet the intent of the 44% requirement. As a good practice, Duke recommends that all facilities be designed to operate at these pf ratings should the situation arise over the life of the facility that the facility would want this capability.

Because the capability curve limit must be satisfied, the vector sum of the active and reactive powers must not exceed the apparent power capability[2]. The reactive capability shall be provided on an inverter capability curve (P-Q graph) and shall be based at the rated voltage of the device (1 pu) and an ambient temperature of 35° C. The DER may choose to submit reactive capability data on a higher ambient temperature basis, however that data will still be applied as the 35° C capability (Duke cannot temperature adjust manufacturer data).

Because operating points on the chart can be difficult to accurately determine, it is recommended that the DER provide the numerical data that defines critical points on the capability curve. Those points include the Nameplate and Configuration apparent, active, and reactive power ratings at the leading, lagging, and unity power factors.

Some facilities have operational, design, or other limitations that prevent utilization of the full reactive capability of the device(s). If that is the case, the DER shall specify any factors that limit or de-rate the output of the generator (e.g., collector system voltage limits, auxiliary voltage limits, net meter load voltage limits, current limits, and specific ambient temperature conditions). If no limitations are submitted, then Duke will consider that the facility has no reactive capability limitations. Duke recommends submittal of a facility capability curve that includes any limitations.

Supplemental Devices

If the DER includes supplemental devices, capability data must be provided for each device at rated voltage of the device and an ambient temperature of 35° C. Subject to the same conditions above, the DER may

[2] See the EPRI document "Understanding Watt and Var Relationships in Smart Inverters", 3002015102

elect to submit data at a higher ambient temperature. For a dynamic device, capable of varying output magnitude, a capability curve must be provided with a brief written description and an acceptable power flow model of the device. If the supplemental device is static (i.e. a fixed capability), then a curve is not required, but the appropriate capability data must be provided and the type of device identified. Additionally, if there are multiple devices that form the complete DER, a composite capability curve that includes all sources, loads, and supplemental devices shall be provided.

Again, any limitations that prevent the full reactive capability of the device(s) to be utilized shall be specified and Duke recommends submittal of a facility capability curve that includes the limitations.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to evaluate design documents and equipment specifications to determine reactive power capability. A field test may be required for DER to prove its reactive power capability. Duke expects to follow the commissioning tests requirements in IEEE 1547.1 to cover this topic.

Implementation of this section requires publishing the final position and integrating verification requirements into the overall commissioning test program.

SECTION 5.3 – VOLTAGE AND REACTIVE POWER CONTROL

The Standard lists several forms of reactive power control:

- Constant power factor mode
- Constant reactive power mode
- Voltage-reactive power mode
- Active power-reactive power mode

Constant reactive power is not thought to be a particularly useful control mode. Constant power factor is the broad category of control that includes unity power factor, which can be useful, but is limited by operating at a control point that is not based on feeder conditions. Duke is in the process of performing studies that will focus on voltage-reactive power mode and active power-reactive power mode for UDER. The Duke study will evaluate the application and consequences of these functions.

Part of the study effort is to determine if voltage regulation functions should be activated and how they should be configured. Before using these functions on a widespread basis, Duke Energy will evaluate the system impacts, identify any unanticipated effects, and then assess the control modes and settings. Because the impact of UDER reactive injection can be large, Duke limits the reactive capability that can be used for reactive power control to 0.95 power factor.

In North and South Carolina utility scale solar, UDER, is the majority of the solar capacity installed. Therefore, study efforts will focus on that type of facility. In due time, there should be some consideration for residential-scale inverters as well. The reactive control method and settings should consider existing operational requirements as well as mitigation of the high voltages that can occur with the addition of DER.

No change can be made on one part of the system that does not affect another part. Therefore, the study will also consider the magnitude of influence the inverter has on voltage, reactive power flow impacts, remediation of impacts, and controlling the impact on the transmission system. Distribution Providers must comply with agreements and requirements of the transmission entities. As such, an evaluation of transmission impacts is important.

Significant technical studies are required to evaluate these functions and analyze the consequences. The studies began at the end of 2019 and will continue in 2021. This will continue to be an agenda item for the TSRG meetings will focus on the most useful control modes and settings that are applied locally in the inverter and are autonomous.

Duke Energy has reviewed and considered all TSRG and submitted comments up to the date of this revision.

Interoperability requirements: To be determined.

Even with autonomous operation there will be some requirements to communicate the VAR priority mode and reactive power mode to Duke, and possibly other information. Because those requirements are not known at this time, Duke must perform additional analysis and interface testing for autonomous operation. For example, some DER require a 0-100% setpoint while others require an actual value in kVAR. In the future, there may be value in providing the necessary controls for remote utility control. That is second priority to autonomous operation, but that would require even more controls and monitoring. While priority can be enabled/disabled with a Binary Output, separate Analog Outputs must be used to set the individual control setpoints for each mode.

At this time, Duke does not have the capability to remotely control or manage distribution connected reactive power resources. However, there is some expectation that functionality may be necessary or available within the life of the DER. Facilities may want to make provision for interoperability capabilities that include both autonomous operation as well as remote control and adjustment of setpoints.

Verification and test requirements: To verify DER compliance to this requirement, Duke will require evaluation of the volt-var settings and field settings verification. Due to complication of performing voltage tests in the field, Duke does not plan to require field commissioning test on this topic. Operational data may be required to evaluate the DER's performance meeting this requirement.

Additional analysis must be performed before finalizing the Verification and test requirements.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface, and integrating verification requirements into the overall commissioning test program.

SECTION 5.4 – VOLTAGE AND ACTIVE POWER CONTROL

The main requirement here involves subsection 5.4.2, Voltage-active power mode. The voltage-active power mode serves as a backup to voltage control. Should an unexpected high voltage condition arise, or the voltage cannot be controlled by the local reactive resources, the voltage-active power control will reduce the DER active power to assist with voltage control

The settings and specifications for voltage-active power control are included with the study discussed for Section 5.3.

Interoperability requirements: To be determined.

Even with autonomous operation there will be some requirements to communicate the mode and possibly other information. Because those requirements are not known at this time, Duke must perform additional analysis and interface testing for autonomous operation.

Duke has the initial I/O points for active power control. The SCADA interface required and operations and functional requirements are still to be determined.

In the future, there may be value in providing the necessary controls for remote utility control. That is second priority to autonomous operation, but that would require even more controls and monitoring. While the mode can be enabled/disabled with a Binary Output, separate Analog Outputs must be used to set the individual control setpoints.

Verification and test requirements: To verify DER compliance to this requirement, Duke will require evaluation of the volt-watt settings and field settings verification. Due to complication of performing voltage tests in the field, Duke does not plan to require field commissioning test on this topic. Operational data may be required to evaluate the DER's performance meeting this requirement.

Additional analysis must be performed before finalizing the Verification and test requirements.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface, and integrating verification requirements into the overall commissioning test program.

SECTION 6.2 – AREA EPS FAULTS AND OPEN PHASE CONDITIONS

Duke Energy has not determined the guidelines for this section. While the Standard may be accepted as written, there may need to be clarifications.

This is a sub-task of an ongoing project involving the Protection and Transmission Planning groups. There is an enormous effort to model the system, perform iterative studies, perform the research, and evaluate protection settings. Duke Energy is working to determine the best DER recloser protection elements to optimize protection and ride-through performance and establish the abnormal operating performance Categories.

Interoperability requirements: To be determined.

Duke Energy must evaluate if there are any interoperability requirements for this section.

Verification and test requirements: The existing inspection and commissioning process covers the verification of this requirement. Duke plans to continue the practice and refine the process as necessary following the commissioning test requirements in IEEE 1547.1.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface.

SECTION 6.3 – AREA EPS RECLOSING COORDINATION

Duke Energy has not determined the guidelines for this section. While the Standard may be accepted as written, there may need to be clarifications.

This is a sub-task of an ongoing project involving the Protection and Transmission Planning groups. There is an enormous effort to model the system, perform iterative studies, perform the research, and evaluate protection settings. Duke Energy is working to determine the best DER recloser protection elements to optimize protection and ride-through performance and establish the abnormal operating performance Categories.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: For large scale DER that is equipped with a Duke PCC recloser, such coordination will be considered under the Duke Energy DER Enterprise Standards. For other DER, Duke will follow the commissioning tests requirements in IEEE 1547.1.

Implementation of this section requires publishing the final position.

SECTION 6.4.1 – MANDATORY VOLTAGE TRIPPING REQUIREMENTS

Duke Energy has not determined the guidelines for this section.

This is a sub-task of an ongoing project involving the Protection and Transmission Planning groups. There is an enormous effort to model the system, perform iterative studies, perform the research, and evaluate protection settings. Duke Energy is working to determine the best DER recloser protection elements to optimize protection and ride-through performance and establish the abnormal operating performance Categories. As placeholders, the present trip setpoints are added to the Guidelines.

Consensus was reached with Transmission System Planning and Operations for POI Recloser voltage and frequency settings and time delays that provide adequate ride-through for BES events. The team is still reviewing the impact to system protection with the proposed settings.

For new DER installations, the present voltage tripping setpoints are provided in the table below.

Parameter	Voltage	Time
Undervoltage, UV Level 1	0.88 pu	10 cycles
Undervoltage, UV Level 2	0.5 pu	6 cycles
Overvoltage, OV Level 1	1.1 pu	10 cycles
Overvoltage, OV Level 2	1.2 pu	6 cycles

Interoperability requirements: To be determined.

It is expected that these values will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: The existing inspection and commissioning process covers the voltage trip settings field verification and Duke plans to continue that practice. Due to complication of performing abnormal voltage tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

SECTION 6.4.2 – VOLTAGE DISTURBANCE RIDE-THROUGH REQUIREMENTS

Duke Energy has not determined the guidelines for this section, but these requirements are being developed concurrently with Section 6.4.1 – Mandatory voltage tripping requirements.

See Section 1.4 for the abnormal performance category.

Interoperability requirements: To be determined.

It is expected that these values will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: To verify DER compliance, Duke will require evaluation of the DER ride-through settings and field setting verification. Due to complication of performing abnormal voltage tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

6.4.2.6 Dynamic voltage support

At least one Duke region requires dynamic reactive compensation for transmission connected DER. Application for the distribution system is still under evaluation.

SECTION 6.5.1 – MANDATORY FREQUENCY TRIPPING REQUIREMENTS

Duke Energy has not determined the guidelines for this section, but these requirements are being developed concurrently with Section 6.4.1 – Mandatory voltage tripping requirements. As placeholders, the present trip setpoints are added to the Guidelines.

For new DER installations, the present frequency tripping setpoints are provided in the table below.

Parameter	Frequency	Time
Underfrequency, UF	57 Hz	10 cycles
Overfrequency, OF	60.8 Hz	10 cycles

Interoperability requirements: To be determined.

It is expected that these values will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: The existing inspection and commissioning process covers the frequency trip settings field verification and Duke plans to continue that practice. Due to complication of performing abnormal frequency tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

SECTION 6.5.2 – FREQUENCY DISTURBANCE RIDE-THROUGH REQUIREMENTS

For sections 6.5.2.1 through 6.5.2.4, concerning frequency ride-through:

Duke Energy has not determined the guidelines for this section, but these requirements are being developed concurrently with Section 6.4.1 – Mandatory voltage tripping requirements.

The Standard also includes several subsections related to frequency. Although Duke Energy considers these requirements mainly as functional specifications for the inverter, Duke Energy does have additional requirements or clarifications.

6.5.2.5 Rate of change of frequency (ROCOF)

UL certification testing should verify the inverter will ride through a 3 Hz/s excursion. That being the case, no generator on the utility system shall intentionally trip for ROCOF using protective relaying or DER controller functions. DER tripping for ROCOF, if available, should be off or disabled. The DER shall certify that protective relay settings & controller settings do not intentionally trip for ROCOF.

This function, either at the inverter or the utility PCC recloser, is still under evaluation. Duke anticipates adopting the 1547 requirements if that is supported by the ongoing project.

6.5.2.6 Voltage phase angle changes ride-through

This function, either at the inverter or the utility PCC recloser, is still under evaluation. Duke anticipates adopting the 1547 requirements if that is supported by the ongoing project.

6.5.2.7 Frequency-droop (frequency-power) capability

This function is still under evaluation. Per Standard table 22, a specification of the droop, deadband, and associated parameters is required for Category III.

6.5.2.8 Inertial response

Duke Energy has not determined the guidelines for this subsection. This capability is not required by the Standard but is permitted.

Interoperability requirements: To be determined.

It is expected that these values for Section 6.5.2 will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: To verify DER compliance, Duke will require evaluation of the DER ride-through settings and field setting verification. Due to complication of performing abnormal frequency tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

SECTION 7.2.2 – RAPID VOLTAGE CHANGES

Duke has an existing process that is part of the system impact study to assess the risk of Rapid Voltage Changes (RVC) and require mitigation if necessary. Duke considers that the existing RVC criteria is consistent with the Standard and does not plan further evaluation.

Interoperability requirements: To be determined.

Based on the type of inrush mitigation used, there could be some status points that are useful for situational awareness. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements.

Verification and test requirements: The installation evaluation is currently included in the scope of Duke's interconnection inspection process, but the performance of the mitigation is not currently tested. A power quality meter is required for the field tests. Duke plans to evaluate the DER RVC impact and mitigation performance by reviewing the data collected during the commissioning test (such as cease-to-energize test).Duke will develop a test procedure and criteria to evaluate the performance of a RVC mitigation solution as part of the commissioning tests.

Implementation of this section requires applying the interoperability functionality in the local interface and integrating verification requirements into the overall commissioning test program.

SECTION 7.2.3 – FLICKER

Duke Energy adopts these requirements as written in the Standard. Note that Duke also applies IEEE 1453 recommended practices.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review design document and equipment specification to evaluate the potential flicker cause DER. A power quality meter is required for the field tests. Duke plans to follow the commissioning tests requirements in IEEE 1547.1. Operational data collection after a DER or system event may be required to validate proper DER operation.

This section is ready to be implemented.

SECTION 7.3 – LIMITATION OF CURRENT DISTORTION

Duke Energy adopts these requirements as written in the Standard. The industry has found that the inverter designs are reaching and exceeding the harmonic monitoring capabilities of existing measurement devices. Therefore, Duke Energy requires the DER owner to mitigate all order harmonics to no greater than 0.3% if the harmonics affect other customers. Harmonic limits shall be aggregated and applied during the DER hours of operation.

Interoperability requirements: No specific requirements for this section. Installation of a power quality meter is already part of the required design for DER 1 MW and greater.

Verification and test requirements: Duke plans to follow the commissioning tests requirements in IEEE 1547.1.

This section is ready to be implemented.

SECTION 7.4.1 – LIMITATION OF OVERVOLTAGE OVER ONE FUNDAMENTAL FREQUENCY PERIOD

Duke Energy adopts these requirements as written in the Standard.

Part of 7.4.1 is based on the inverter design and operation and part is based on the specific design of the interconnection and the Area EPS itself. The ability of the inverter to detect and limit overvoltage will be verified by UL certification testing. However, the DER facility must still be analyzed during system impact study to verify the impact of the combined inverter and Area EPS is below the limits of the Standard. The limits defined in parts a) and b) must be verified by power system study.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to rely on UL certification testing, review type tests results, and examine design documents to evaluate the potential overvoltage contribution from DER. Duke plans to develop a test procedure and criteria for transient overvoltage during the commissioning test. A power quality meter is required for the field tests. Duke plans to follow the commissioning tests requirements in IEEE 1547.1.

This section is ready to be implemented.

SECTION 7.4.2 – LIMITATION OF CUMULATIVE INSTANTANEOUS OVERVOLTAGE

Duke Energy has not determined the guidelines for this section. More industry experience or analysis could be essential to address this issue. Duke does not plan to implement this section until IEEE 1547.1 is revised and UL 1741 certification tests include this verification. At that time, Duke expects to adopt these requirements as written in the Standard.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review type tests results and design documents to evaluate the potential overvoltage contribution from DER. Duke plans to develop a test procedure and criteria for transient overvoltage during the commissioning test. A power quality meter is required for the field tests. Duke plans to follow the commissioning tests requirements in IEEE 1547.1.

Implementation of this section requires publishing the final technical position.

SECTION 10.3, 10.4 – NAMEPLATE AND CONFIGURATION INFORMATION

These sections address the two broad types of information available through the local DER communication interface. The following terms are listed in decreasing order of magnitude. The value of each parameter in the list is greater than or equal to the value of the parameter below it:

Nameplate Apparent Power Maximum Rating
Configuration Apparent Power Maximum Rating
Nameplate Active Power Rating (unity power factor)
Configuration Active Power Rating (unity power factor)

The list above does not address all the terms in the table. Such a specification is not necessary of every term, but helpful to clarify for some. Duke will consider addressing other terms as needed. Consequently, operational limits and settings, such as the Active Power Limit, cannot be greater than the ratings (not applicable to abnormal or protection settings).

Ratings are considered a permanent characteristic of a device or a system and are characterized by:

- Rating is the full capacity of the equipment or system.
    - The rating is the most capacity the system is designed to provide
- Rating represents a continuous capacity. Operation at the Rating can continue for indefinitely long periods without exceeding design limits and without reducing the life or maintenance interval.
    - Also, there can be short-term ratings that are time limited. Operation within the parameter and time limit does not exceed design limits or negligibly reduce the life or maintenance interval.

- Rating is the base upon which other model, analysis, and inverter parameters are referenced.
- Ratings are a common way to identify and classify devices.

Limits are not included in these sections of the Standard. However, their relationship to and differences from ratings are important. Limits are adjustable, provide boundaries not to be exceeded, and are less than or equal to ratings. Limits are characterized by:

- Limits impose boundaries on device operation, often to restrict operation within ratings.
- Limits can be established or defined by contractual, system design, or physical equipment restrictions.
- Limits are set for a controlled variable and must not be exceeded (e.g. boundary condition).
- Limits are often stated as a percent of the rating (therefore necessitating a fixed rating value).

The Nameplate Active Power Rating is an important design parameter for the DER, but also as an important base parameter for modeling. The same for Nameplate Apparent Power Maximum Rating, for some equipment or models, parameters may be specified in terms of percent of Nameplate Apparent Power or Nameplate Active Power Rating. In cases where operation to the full Nameplate Active Power Rating is not acceptable for the application, then the Configuration Active Power Rating can be set to establish a lower rating. While the minimum of these two values sets the overall rating, it can be important to distinguish between these when it comes to equipment specifications and modeling.

UNADDRESSED REQUIREMENTS OF IEEE 1547-2018

The remaining IEEE 1547-2018 clauses and sections not discussed above will be undertaken following the completion of the higher priority topics. Concerning the clauses and sections not addressed in this document, Duke Energy expects that the DER shall conform to the Standard itself as written.

APPENDIX – IEEE 1547-2018 BENCHMARKING

Duke Energy requested that Navigant Consulting, Inc. to facilitate the stakeholder discussion at the January 2020 TSRG meeting and to perform benchmarking. The following table was developed by Navigant Consulting, Inc.

TABLE B.1. BENCHMARKING OF IEEE 1547-2018 FUNCTIONALITIES IMPLEMENTATION

IEEE 1547 Section	Topic	Duke Order (pre-stakeholder)	Minnesota/ Colorado (Xcel Energy)	Ameren / MISO
6.4.2	Voltage disturbance ride-through requirements	1	1	1
5.3	Voltage and reactive power control	1	1	1
6.5.2	Frequency disturbance ride-through requirements	2	1	1
6.4.1	Mandatory voltage tripping requirements (OV/UV)	1	1	2
5.4.2	Voltage-active power control	1	1	2
6.5.2.7	Frequency-droop (frequency-power) capability	2	1	2
6.5.1	Mandatory frequency tripping requirements (OF/UF)	2	1	2
5.2	Reactive power capability of the DER	1	1	
4.5	Cease to energize performance requirement [Reliability]	3	2	
4.6.1	Capability to disable permit service	3	2	
4.6.2	Capability to limit active power	3	2	
4.10.2	Enter service criteria	4	3	2
7.2.2	Power Quality, Rapid voltage change (RVC)	1	3	
4.10.3	Performance during entering service	4	3	
4.10.4	Synchronization	4	3	
4.2	Reference points of applicability (RPA) [Interconnection]	4	3	
6.5.2.5	Rate of change of frequency (ROCOF)	4	4	1
4.10	Enter service [Reliability] // 6.6 Return to service after trip	4	4	2
6.4.2.6	Dynamic voltage support		4	2
4.3	Applicable voltages [Manufacturer]	4	4	
4.11.3	Paralleling device	4	4	
6.2	Area EPS faults and open phase conditions [Reliability]		4	
6.3	Area EPS reclosing coordination [Reliability]		4	

IEEE 1547 Section	Topic	Duke Order (pre-stakeholder)	Minnesota/ Colorado (Xcel Energy)	Ameren / MISO
10.2	Monitoring, control, and information exchange requirements		4	
10.5	Monitoring information		4	
10.1	Interoperability requirements		4	
10.3	Nameplate Information		4	
10.4	Configuration information		4	
10.6	Management information		4	
10.7	Communication protocol requirements		4	
10.8	Communication performance requirements		4	
10.9	Cyber security requirements		4	
11	Test and verification		4	
8.2	Intentional islanding		4	
11.4	Fault current characterization		4	
9	Secondary network		4	
4.6.3	Execution of mode or parameter changes [Manufacturer]		4	
6.5.2.6	Voltage phase angle changes ride-through	2		1
6.4.2.5	Ride-through of consecutive voltage disturbances			1
7.2.3	Power Quality, Flicker	1		
7.4	Limitation of overvoltage contribution	1		
6.5.2.8	Inertial response			
7.3	Limitation of current distortion			
8.1	Unintentional islanding			
4.7	Prioritization of DER responses			
4.8	Isolation device [Interconnection]			
4.11.1	Protection from electromagnetic interference			
4.11.2	Surge withstand performance			
4.12	Integration with Area EPS grounding [Reliability]			
4.13	Exemptions for Emergency Systems and Standby DER			
4.9	Inadvertent energization of the Area EPS [Interconnection]			

1

Implementation of IEEE 1547-2018 Guidelines for Duke Energy Carolinas and Duke Energy Progress

Duke Energy

Duke Energy Carolinas and Duke Energy Progress

Distributed Energy Technology

DER Technical Standards

Revision 4

April 28, 2021

Implementation of IEEE 1547-2018 Guidelines for Duke Energy Carolinas and Duke Energy Progress

Revision	Date	Description
0	3/31/2020	Initial issue
1	7/21/2020	General update prior to July 2020 TSRG meeting
2	10/28/2020	General update prior to Oct. 2020 TSRG meeting
3	1/20/2021	General update prior to Jan. 2021 TSRG meeting
4	4/28/2021	General update prior to Apr. 2021 TSRG meeting

CONTENTS

INTRODUCTION

Duke Energy seeks to implement smart inverter technical specifications and requirements as defined in the updated IEEE Standard 1547-2018, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems (IEEE 1547 or the Standard). This document focuses only on the distributed energy resources (DER) connected to the distribution system and not those connected to the transmission or bulk power system (BPS). In North and South Carolina, the implementation of IEEE 1547 is focused on large utility scale DER (UDER) because there had been significant number of those installations. Some of IEEE 1547 requirements are also applicable to the smaller retail and residential DER (RDER). If there are any variations in application of the Standard to UDER and RDER, those conditions will be noted in this document.

Note to the format of this document. This guideline is meant to be a living document. For now, it captures where Duke Energy is in the process of implementing IEEE 1547-2018. This document notes sections of the standard that require no additional analysis or review and those that are under review and those that must still be reviewed. In sections highlighted like this paragraph, there will be a brief discussion of the ongoing work to be concluded to address implementation of that Standard section.

The standard is an inverter Standard and not a utility standard, therefore many parts of the Standard can be implemented by Duke Energy simply by adopting IEEE 1547-2018 as the applicable standard for Duke Energy inverter based interconnections. However, there are some sections of the Standard that require input or specifications from the utility. The Standard specifies inverter capabilities and functions, but not utilization. The purpose of this document is to clarify any additional information for utilization.

The standard is applicable to DER connected at the primary or secondary distribution system voltage levels. However, some of the Standard requirements are based on conditions and issues related to the BES. There can be situations where the aggregate distribution DER capacities are large enough to impact the NERC BES reliability. In those cases, BES requirements are implemented in DER connected to the distribution system. However, these requirements are not directly distribution requirements, but BES requirements applied at the distribution power system level. The interaction between the BES and the distribution system is well covered in the NERC Reliability Guideline: Bulk Power System Reliability Perspectives on the Adoption of IEEE 1547-2018. The guideline recommends that the BPS entities (BA, RC, PC, TP) coordinate with the Distribution Providers (DP) to achieve successful implementation of the Standard.

This Duke Energy Guideline is applicable to DER located in the Duke Energy service territories in North Carolina and South Carolina. The Guidelines have been developed based on input and comments from TSRG stakeholders.

CONSIDERATION OF IEEE 1547 SECTIONS THAT COULD INCREASE INTERCONNECTION CAPABILITY

The following IEEE 1547 controls or functions are the primary functions that could potentially increase the amount of DER capacity (higher penetration) that can interconnect with minimal feeder upgrades:

i) 4.6.2 Capability to limit active power
ii) 5.3 Voltage and reactive power control
iii) 5.4 Voltage and active power control

While power quality issues can still restrict interconnection, the voltage and reactive power controls are a potential mitigation to those issues too.

While there are other inverter functions that improve reliability of the interconnection, the inverter functions listed above would be the primary drivers for adding more DER capacity to a feeder. Therefore, these functions were assigned a higher priority to review and analyze.

CONSIDERATION OF IEEE 1547 SECTIONS THAT IMPACT GRID SUPPORT

In addition to prioritizing assessment of those sections of IEEE-1547 that could increase interconnection capability, the Companies are also prioritizing those sections that could impact grid support. The 2003 version of the standard created reliability concerns by not providing voltage regulating capability and tripping for abnormal system conditions. While the 2014 version addressed some of the grid reliability concerns, 2018 provides even more inverter capabilities. Also, documents such as the NERC Reliability Guideline: Bulk Power System Reliability Perspectives on the Adoption of IEEE 1547-2018 focus "on ensuring reliable operation of the BPS under increasing penetrations of BPS-connected inverter-based resources as well as distributed energy resources (DERs)." One objective of such documents is to encourage timely adoption of the IEEE 1547-2018 that are likely to impact or support the BPS.

The priority of review of the Standard sections identified in the table is consistent with this industry guidance in that many of the first and second priority selected topics were noted in the NERC guideline as well. Sections 4.2 and 4.10.2 are fourth priority for Duke, but that is mainly because these topics are thought to be more straightforward to address and will likely not require significant evaluation. Interoperability was noted by NERC and Duke plans to address that on a topic by topic basis rather than as one stand-alone interoperability topic. In this way, interoperability is addressed concurrent with the technical considerations for each topic.

The following topics are yet unranked by Duke, but they are in the NERC guideline: 6.4.2.7, 6.5.2.8, 8.1, 8.2. Section 6.4.2.7 was added to the Duke list after the NERC guideline review. These were not ranked during the Duke process because of the lower priority placed on them by the TSRG stakeholders and Duke. These are also topics that need more time and investigation by the industry, so addressing some of the better understood and higher prioritized items first is a reasonable path forward.

PRIORITY OF IMPLEMENTING THE IEEE 1547 TECHNICAL SPECIFICATIONS AND REQUIREMENTS

There are many aspects of implementing the Standard that must be considered. The technical specifications and requirements must be understood and assessed to determine if there is a need to clarify any technical points for consistent application across the Duke system. Duke subject matter experts, TSRG stakeholders, NC Public Staff, and industry documents were included in the activity to set priority for the various Standard sections. The areas of the Standard that stand out as most important are the ride through capability and voltage and reactive power controls.

Below is the priority order at this time considering all TSRG input. If there is no priority stated in the list, then the priority of those items is yet to be assigned. Note that the priority group and the assigned Duke identification number[1] for that item are both in the first column. The remaining IEEE 1547-2018 clauses and sections that do not have a priority assigned will be undertaken following the completion of the higher priority topics. The three columns on the far right side of the table summarize the status for the technical, interoperability, and verification and test aspects for each Standard topic. Many of the summaries are not the final decision because the topic requires more analysis and assessment. However, this table still provides a general overview.

[1] Only the prioritized Duke identification numbers represent the sequence of evaluation, and are numbered less than 100. Numbers greater than 100 are temporarily assigned to the topic until that topic is given a specific priority.

Duke Energy Selected Order of Precedence for IEEE 1547 Sections

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
1 (DUK-01)	5.2	Reactive power capability of the DER	Category B	No Reqmt	Eval + Comm Test
1 (DUK-02)	5.3	Voltage and reactive power control	Study in progress	Yes	Eval + Comm Test
1 (DUK-03)	5.4.2	Voltage-active power control	Study in progress	Yes	Eval + Comm Test
1 (DUK-04)	7.4	Limitation of overvoltage contribution	Accept 1547 with additional requirements	No Reqmt	Eval + Comm Test
1 (DUK-05)	7.2.3	Power Quality, Flicker	Accept 1547 in conjunction with continued use of IEEE 1453	No Reqmt	Eval + Comm Test
1 (DUK-06)	7.2.2	Power Quality, Rapid voltage change (RVC)	Continue existing criteria and policy	TBD	TBD, Eval + Comm Test
2 (DUK-07)	6.4.1	Mandatory voltage tripping requirements (OV/UV)	Have existing setpoints; new 1547 setpoint study in progress	TBD	Eval + Comm Test
2 (DUK-08)	6.5.1	Mandatory frequency tripping requirements (OF/UF)	Have existing setpoints; new 1547 setpoint study in progress	TBD	Eval + Comm Test
2 (DUK-09)	6.4.2	Voltage disturbance ride-through requirements	Study in progress	TBD	Eval + Comm Test
2 (DUK-10)	6.5.2	Frequency disturbance ride-through requirements	Study in progress	TBD	TBD, Eval + Comm Test
2 (DUK-11)	6.5.2.7	Frequency-droop (frequency-power) capability	Evaluation has not begun	No Reqmt	TBD, Eval + Comm Test
2 (DUK-12)	6.5.2.6	Voltage phase angle changes ride-through	Study in progress	No Reqmt	TBD, Eval + Comm Test
3 (DUK-13)	4.5	Cease to energize performance requirement	Accept 1547 as written	No Reqmt	Eval + Comm Test
3 (DUK-14)	4.6.1	Capability to disable permit service	Accept 1547 as written	Yes	TBD, Eval + Comm Test
3 (DUK-15)	4.6.2	Capability to limit active power	Accept 1547 as written	Yes	TBD, Eval + Comm Test
4 (DUK-16)	6.5.2.5	Rate of change of frequency (ROCOF)	Study in progress	TBD	TBD, Eval + Comm Test

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
4 (DUK-17)	4.2	Reference points of applicability (RPA)	Accept 1547 as written; consider clarifications	No Reqmt	TBD, Eval.
4 (DUK-18)	4.3	Applicable voltages	Accept 1547 as written; consider clarifications	Yes	TBD, Eval.
4 (DUK-19)	4.10.2	Enter service criteria // 6.6 Return to service after trip	Accept 1547 as written; consider clarifications	TBD, Yes	TBD, Eval + Comm Test
4 (DUK-20)	4.10.3	Performance during entering service	Accept 1547 as written; consider clarifications	TBD, Yes	Eval + Comm Test
4 (DUK-21)	4.10.4	Synchronization	Accept 1547 as written; consider clarifications	No Reqmt	TBD, Eval + Comm Test
4 (DUK-22)	4.11.3	Paralleling device	Accept 1547 as written	No Reqmt	Type Test
5 (DUK-23)	4.9	Inadvertent energization of the Area EPS	Accept 1547 as written	No Reqmt	Eval + Comm Test
5 (DUK-24)	6.3	Area EPS reclosing coordination	Accept 1547 as written; consider clarifications; part of ongoing study	No Reqmt	Eval.
5 (DUK-25)	6.2	Area EPS faults and open phase conditions	Accept 1547 as written; consider clarifications; part of ongoing study	TBD	Eval + Comm Test
5 (DUK-26)	4.12	Integration with Area EPS grounding	Accept 1547 with clarifications	No Reqmt	Eval.
5 (DUK-27)	4.7	Prioritization of DER responses	Accept 1547 as written	No Reqmt	TBD, Eval + Comm Test
5 (DUK-28)	4.8	Isolation device	Accept 1547 as written	No Reqmt	Eval + Comm Test
5 (DUK-29)	4.11.1	Protection from electromagnetic interference	Accept 1547 as written	No Reqmt	Type Test
5 (DUK-30)	4.11.2	Surge withstand performance	Accept 1547 as written	No Reqmt	Type Test
5 (DUK-31)	4.6.3	Execution of mode or parameter changes	Accept 1547 as written	TBD, Yes	TBD, Eval + Comm Test
- (DUK-101)	9	Secondary network	Duke does not currently have these	No Reqmt	-
- (DUK-102)	11.4	Fault current characterization	TBD	No Reqmt	-

DUKE ENERGY.

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
- (DUK-103)	8.1	Unintentional islanding	TBD	Yes	-
- (DUK-104)	8.2	Intentional islanding	TBD	Yes	-
- (DUK-105)	11	Test and verification	TBD	-	-
- (DUK-106)	10.2	Monitoring, control, and information exchange requirements	TBD	Yes	-
- (DUK-107)	10.5	Monitoring information	TBD	Yes	-
- (DUK-108)	6.4.2.5	Ride-through of consecutive voltage disturbances	TBD	No Reqmt	-
- (DUK-109)	6.4.2.6	Dynamic voltage support	TBD	No Reqmt	-
- (DUK-110)	6.5.2.8	Inertial response	TBD	No Reqmt	-
- (DUK-111)	10.1	Interoperability requirements	TBD	Yes	-
- (DUK-112)	10.3	Nameplate Information	TBD	Yes	-
- (DUK-113)	10.4	Configuration information	TBD	Yes	-
- (DUK-114)	10.6	Management information	TBD	Yes	-
- (DUK-115)	10.7	Communication protocol requirements	TBD	Yes	-
- (DUK-116)	10.8	Communication performance requirements	TBD	Yes	-
- (DUK-117)	10.9	Cyber security requirements	TBD	Yes	-
- (DUK-118)	7.3	Limitation of current distortion	TBD	TBD	-
- (DUK-119)	4.13	Exemptions for Emergency Systems and Standby DER	TBD	TBD	-
- (DUK-120)	6.4.2.7	Restore output with voltage ride-through	TBD	No Reqmt	0

1

LOGISTICS OF IMPLEMENTING OF IEEE 1547-2018

After the technical aspects of each Standard section are understood, Duke Energy can then determine the necessary changes to implement that section. This could vary from taking no action, to updating documentation, to changing work, study, and operational practices. Additionally, a consequence of more inverter functions will be the necessary increase in interoperability requirements as well as DER equipment and DER system verification and testing to confirm design and functional requirements. There are many aspects to consider before implementing each 1547 section. Because the actions to implement each section can vary widely, the implementation will be addressed in each section rather than as a whole for the entire Standard.

It is understood that many of the functions will not be available until IEEE 1547-2018 certified inverters are tested and available to the market. At that time, Duke Energy shall require all inverters to be IEEE 1547-2018 certified. All functions and requirements may not be applicable or implemented at the time the inverters become certified or that Duke Energy requires the certification.

Duke Energy has no plans to implement the new functions of IEEE 1547-2018 for existing inverters. Not only it is not a common practice at Duke to retroactively apply standards, it is really not even a valid concern because existing inverters do not have many of the 1547-2018 capabilities and are not tested to UL 1741 SB. If a 1547-2018 function is implemented and there is a comparable IEEE 1547a-2014 function for inverters certified to UL 1741 SA, then Duke Energy and the DER Owner may mutually agree to implement those available functions as needed. Similarly, some functions like voltage and frequency tripping have existed throughout all versions of 1547. Revising pre-existing settings is not considered implementation of a new function.

PLANT REQUIREMENTS

Guidelines must consider how all sections may apply if implemented on a plant-scale with a power plant controller rather than at the individual inverter units. There may need to be some tests for verification that the plant controller performs the intended functions and that the underlying inverters to not behave contrary to the plant controller configuration or commands.

Note that in the following part of this document, the title of each section is the IEEE 1547-2018 section or subsection number and title.

SECTION 1.4 – GENERAL REMARKS AND LIMITATIONS

Duke Energy accepts the scope of the Standard as specified in this section. For UDER, the single point of common coupling (PCC) is located at the boundary between the utility electric power system (EPS) and the local EPS or DER EPS.

The technical specifications and requirements for some performance categories are specified by general technology-neutral categories. For categories related to reactive power capability and voltage regulation performance requirements, Duke Energy requires the following normal performance category:

Voltage and Reactive Power Category B

For categories related to response to Area EPS abnormal conditions, Duke Energy requires the following abnormal operating performance categories:

Synchronous generation	Category I
Induction generation	Mutual agreement
Inverter-based generation	Category III*
Inverter-based storage	Category III*

This section shall be applicable once 1547-2018 inverters are certified and required or if by mutual agreement between Duke Energy and the DER Owner for inverters certified to IEEE 1547a-2014 or UL 1741 SA.

* Final determination for the Category has not been made. More analysis is required and included as part of a study conducted jointly between the Duke Protection and Transmission Planning groups. This work includes a significant effort to model the system, perform iterative studies, and perform research. The main focus is on Category II and that is expected to be the minimum requirement for IBR. With the amendment to IEEE 1547a-2020 approved and many utilities standardizing on Category III, that is the most likely selection.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Independent laboratory certifications that attest to the normal and abnormal categories shall satisfy verification for this requirement.

Implementation of this section requires publishing the final position and integrating verification requirements into the overall commissioning test program.

SECTION 4.2 – REFERENCE POINTS OF APPLICABILITY (RPA)

Duke Energy requires the RPA for all performance requirements for UDER to be the PCC (point of common coupling), which is also known as the point of delivery or change of ownership point on the medium voltage side of the DER transformer(s). The RPA for net meter installations is the PoC (point of connection) at the inverter terminals.

Pending analysis: The expectation is that Duke can accept the Standard as written, but Duke must still determine if there are any applicable exceptions or clarifications needed given this portion of section 4.2:

Alternatively, for Local EPSs where zero sequence continuity[27] between the PCC and PoC is maintained and either of the following conditions apply, the RPA for performance requirements of this standard may be the *point of DER connection* (PoC), or by mutual agreement between the *Area EPS* operator and the *DER operator*, at any point between, or including, the PoC and PCC:

a) Aggregate DER nameplate rating of equal to or less than 500 kVA, *or*

b) Annual average load demand[28] of greater than 10% of the aggregate DER nameplate rating, and where the Local EPS is not capable of, or is prevented from, exporting more than 500 kVA for longer than 30 s.

For all other Local EPSs meeting either of the conditions a) or b) above but not meeting the requirement for zero sequence continuity, the RPA for performance requirements other than the response to *Area EPS* abnormal conditions specified in 6.2 and 6.4 shall be the PoC, or by mutual agreement between the *Area EPS operator* and the *DER operator*, at any point between, or including, the PoC and PCC. The RPA for performance requirements of 6.2 and 6.4 shall be a point between, or including, the PoC and PCC that is appropriate to detect the abnormal voltage conditions.[29, 30]

Where the RPA is not at the PCC, any equipment or devices in the Local EPS between the RPA and the PCC shall not preclude the DER from meeting the disturbance ride-through requirements specified in 6.4.2 and 6.5.2.[31]

For Local EPS where aggregate DER nameplate rating is greater than 500 kVA, and annual average load demand[28] is greater than 10% of the aggregate DER nameplate rating, and the Local EPS is capable of, and is not prevented from, exporting more than 500 kVA for longer than 30 s, the RPA shall be the PCC and

The final position must consider the variety of RDER and UDER interconnections and identify the RPA for each. In practice, the interconnections have been very straightforward. The default RPA is the PCC. Zero sequence continuity is not a factor for UDER, so the RPA for UDER is the PCC (point of common coupling at the utility interconnection point). The RPA for net meter installations must consider a variety of conditions, as noted in the decision trees, H.1 and H.2. Note that Section 4.12 also addresses grounding and zero sequence continuity.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke will to review DER design documents to confirm the location of the RPA is correct.

Implementation of this section requires publishing the final technical position.

SECTION 4.3 – APPLICABLE VOLTAGES

Duke Energy will consider if there is a need to clarify any technical points for the final version of the guideline, but the expectation is that the section is implemented as written. The expected outcome is that RDER parameters shall be monitored at the inverter terminals and UDER parameters shall be monitored at the EPS voltage level and used for inverter functions.

Interoperability requirements: Applicable voltages are provided to the local DER interface with Duke Energy.

Verification and test requirements: To be determined.

The applicable voltage should be identified in the interconnection process. Duke plans to review design document to verify the DER meet this requirement.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface, and integrating verification requirements into the overall commissioning test program.

SECTION 4.5 – CEASE TO ENERGIZE PERFORMANCE REQUIREMENT

Duke Energy requires cease to energize capability (not delivering power during steady-state or transient conditions) in accordance with the Standard.

A DER can be directed to cease to energize and trip by changing the Permit service setting to “disabled” as described in IEEE 1547 subsection 4.10.3.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review design document and equipment specification to identify the interconnection device that provides the cease-to-energize function. The existing inspection and commissioning process tests to verify the device meets the performance requirement.

This section is ready to be implemented.

SECTION 4.6 – CONTROL CAPABILITY REQUIREMENTS

Duke Energy will consider if there is a need to clarify any technical points for the final version of the guideline, but the expectation is that the capabilities in the following sections will be adopted as written.

Duke accepts the capabilities in the following sections as written:

- 4.6.1 Capability to disable permit service
- 4.6.2 Capability to limit active power
- 4.6.3 Execution of mode or parameter changes

This section of the Standard applies to all DER 250 kW or greater or DER with a local DER communication interface.

For UDER, Duke Energy is still considering implementing the permit service at the inverter or disconnecting at the local EPS.

Application to RDER has not been assessed.

Note that 4.6.2 is essentially part of the system impact study (SIS) process now because the maximum active power capacity (import or export) is often calculated during the SIS if the requested DER capacity is not possible without upgrades. The Standard defines the active power limit as a percentage of the Nameplate Active Power Rating. Duke interprets the referenced rating as the Nameplate Active Power Rating at unity power factor. Consider too that the active power limit is manually set and Duke does not have the capabilities to adjust the limit based on time of day, load, or other variables.

Duke does not plan to implement real-time control during the initial implementation of the Standard. Significant technical studies are required to address concerns and consider remote real-time control of the active power limit. However, it is reasonable to make provision for this potential capability when designing the monitoring and control capabilities of the communication interface.

Interoperability requirements: The present automation controller implementation uses an Analog Output sent via SCADA to control active power.

Verification and test requirements: Duke will review UL certification tests, type tests, design documents, and equipment specifications to identify the capability of the DER to meet this performance requirement. Duke's current policy requires a utility owned interconnection recloser for UDER >= 1MW. In this case the permit service is implemented by controlling the utility owned recloser. For DER >= 250kW and <1MW, Duke allows the option of installing the small DG interface instead of the utility owned recloser. In this case, the permit service is implemented at the DER unit through the small DG interface.

Implementation of this section requires publishing the final technical position.

SECTION 4.7 – PRIORITIZATION OF DER RESPONSES

Duke Energy expects IEEE 1547-2018 compliant inverters to meet all prioritization requirements of this section of the Standard.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review UL certification testing, type tests results, and design documents to evaluate if a DER can meet this requirement.

This section is ready to be implemented.

SECTION 4.8 – ISOLATION DEVICE

Duke Energy requires isolation devices per the Interconnection Agreement, Method of Service Guidelines, and other interconnection documents. This is a current requirement that is unchanged by IEEE 1547-2018.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Existing site evaluation and inspection shall satisfy verification for this requirement.

This section is ready to be implemented.

SECTION 4.9 – INADVERTENT ENERGIZATION OF THE AREA EPS

Duke Energy requires DER not to energize the utility EPS when the utility EPS is de-energized. When there is a planned and designed intentional island, per Section 8.2 Intentional Islanding, that configuration is not considered inadvertent.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke will only accept type-tested DER for small scale installations like RDER. For UDER, the existing inspection and commissioning process covers this requirement.

This section is ready to be implemented.

SECTION 4.10 – ENTER SERVICE

Duke Energy requires the DER to meet the requirements of all the following subsections:

- 4.10.2 Enter service criteria
- 4.10.3 Performance during entering service
- 4.10.4 Synchronization

Duke must still determine the enter service criteria and enter service time delays. Note that while the Standard mentions Range B of ANSI C84.1, that voltage is at the service level (low side of the service transformer) and not at the primary side. Therefore, the settings in the Standard would be more relevant to RDER than UDER that has the RPA and PCC at the primary side of the DER transformer. The RDER values are common in the industry and are Standard defaults.

When entering service, the DER shall not energize the Area EPS until the following conditions are met:

Enter service value	**Parameter Label**	**RDER setting (Service tx sec)**	**UDER setting (DER tx pri)**
Minimum Voltage	ES_V_LOW	≥ 0.917 p.u.	≥ p.u.
Maximum Voltage	ES_V_HIGH	≤ 1.05 p.u.	≤ p.u.
Minimum Frequency	ES_F_LOW	≥ 59.5 p.u.	≥ p.u.
Maximum Frequency	ES_F_HIGH	≤ 60.1 p.u.	≤ p.u.

Note: The parameter labels are based on the publicly available EPRI technical update document number 3002020201, "*Common File Format for Distributed Energy Resources Settings Exchange and Storage.*"

The final UDER settings are still under evaluation. Duke will compare the final voltage trip and ride through settings for UDER with the Standard default settings. Assuming they are compatible, UDER will adopt the same Standard default values.

The DER shall not enter service or ramp faster than the times stated below. A randomized time delay is optional and not currently used within the Duke system. As noted in the standard, DER increasing active power steps greater than 20% of Nameplate Active Power rating shall require approval during the system interconnection study process.

Time Delay	**Parameter Label**	**RDER setting (seconds)**	**UDER setting (seconds)**
Enter Service Delay	ES_DELAY	300	300
Enter Service Ramp Period	ES_RAMP_RATE	300	300
Enter service randomized delay	ES_RANDOMIZED_DELAY	Off	Off

While the active power is ramping during the enter service period, the reactive power shall follow the configured mode and settings.

When connected in parallel with the Area EPS, energy storage DER (ESS) active power rate of change is dependent on the Configuration Active Power Rating per the table below:

Rate of Change Duration	**Parameter Label**		**RDER setting (seconds)**	**UDER setting (seconds)**
ESS ≤ 1 MW	None		2	n/a
ESS > 1 MW	None		n/a	ESS MW rating / (2 MW/sec)

Interoperability requirements: To be determined.

Duke will evaluate if there is value in monitoring the enter service settings.

Verification and test requirements: For 4.10.2 and 4.10.3, Duke plans to verify the enter service and return to service settings in the field. The existing inspection and commissioning process tests to verify DER meets this requirement. For 4.10.4, Duke plans to review UL certification tests, type tests, and design documents to evaluate DER's synchronization capability meeting this requirement. The on-off test during commissioning will field verify DER's synchronization capability.

Implementation of this section requires publishing the final technical position and applying the interoperability functionality in the local interface.

SECTION 4.11 – INTERCONNECT INTEGRITY

Duke Energy requires the DER to meet the requirements of all the following subsections:

4.11.1 Protection from electromagnetic interference
4.11.2 Surge withstand performance
4.11.3 Paralleling device

Duke Energy does not have additional clarifications of these subsections.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: They standard type-testing is satisfactory for Duke.

This section is ready to be implemented.

SECTION 4.12 – INTEGRATION WITH AREA EPS GROUNDING

Duke accepts the Standard; that the grounding scheme of the DER interconnection shall be coordinated with the ground fault protection of the Area EPS. Duke's system is multi-grounded and the DER facilities and design must be compatible with the EPS. Each interconnection is reviewed for ground fault protection and for limiting the potential for creating over-voltages on the Area EPS.

Approved distribution connected utility scale DER transformer winding configurations are listed below. Therefore, configurations that are not listed are not approved. It is possible for an IC to submit another winding configuration, however the technical review will significantly delay evaluation of the IR.

Primary Winding Type (HV)	Secondary Winding Type (LV)	Zero Seq Maintained PCC to POC	Allowed for DER Interconnection	
			Inverter	**Rotating**
Wye-grounded	Wye-grounded	Yes, (w/4-wire LV)	Yes	Yes
Wye-grounded	Wye	No	Yes	No
Wye-grounded	Delta	No	No	Yes

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review the design document to evaluate if a DER can meets this requirement. The existing inspection and commissioning test process will cover this.

This section is ready to be implemented.

SECTION 5.2 – REACTIVE POWER CAPABILITY OF THE DER

Whether or not reactive power capability or voltage control is initially used for the DER, each DER shall submit the required reactive power capability information. This provides the information when it is most readily available and can be recorded in the event that it is needed later.

For categories related to reactive power capability and voltage regulation performance requirements, Duke Energy plans to require the following performance category:

Voltage and Reactive Power Category B

Category B requires a DER reactive power injection capability (lagging) of 44% of nameplate apparent power rating and 44% absorption capability (leading) of nameplate apparent power rating as defined in the Standard. The Standard adopted “44%” as the injection capability for 0.90 pf, but the percentage is actually slightly less, 43.6%. Duke will consider capabilities 43.6% and higher also meet the intent of the 44% requirement. As a good practice, Duke recommends that all facilities be designed to operate at these pf ratings should the situation arise over the life of the facility that the facility would want this capability.

Because the capability curve limit must be satisfied, the vector sum of the active and reactive powers must not exceed the apparent power capability[2]. The reactive capability shall be provided on an inverter capability curve (P-Q graph) and shall be based at the rated voltage of the device (1 pu) and an ambient temperature of 35° C. The DER may choose to submit reactive capability data on a higher ambient temperature basis, however that data will still be applied as the 35° C capability (Duke cannot temperature adjust manufacturer data).

Because operating points on the chart can be difficult to accurately determine, it is recommended that the DER provide the numerical data that defines critical points on the capability curve. Those points include the Nameplate and Configuration apparent, active, and reactive power ratings at the leading, lagging, and unity power factors.

Some facilities have operational, design, or other limitations that prevent utilization of the full reactive capability of the device(s). If that is the case, the DER shall specify any factors that limit or de-rate the output of the generator (e.g., collector system voltage limits, auxiliary voltage limits, net meter load voltage limits, current limits, and specific ambient temperature conditions). If no limitations are submitted, then Duke will consider that the facility has no reactive capability limitations. Duke recommends submittal of a facility capability curve that includes any limitations.

Supplemental Devices

If the DER includes supplemental devices, capability data must be provided for each device at rated voltage of the device and an ambient temperature of 35° C. Subject to the same conditions above, the DER may elect to submit data at a higher ambient temperature. For a dynamic device, capable of varying output magnitude, a capability curve must be provided with a brief written description and an acceptable power flow model of the device. If the supplemental device is static (i.e. a fixed capability), then a curve is not required, but the appropriate capability data must be provided and the type of device identified.

[2] See the EPRI document “Understanding Watt and Var Relationships in Smart Inverters”, 3002015102

Additionally, if there are multiple devices that form the complete DER, a composite capability curve that includes all sources, loads, and supplemental devices shall be provided.

Again, any limitations that prevent the full reactive capability of the device(s) to be utilized shall be specified and Duke recommends submittal of a facility capability curve that includes the limitations.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to evaluate design documents and equipment specifications to determine reactive power capability. A field test may be required for DER to prove its reactive power capability. Duke expects to follow the commissioning tests requirements in IEEE 1547.1 to cover this topic.

Implementation of this section requires publishing the final position and integrating verification requirements into the overall commissioning test program.

SECTION 5.3 – VOLTAGE AND REACTIVE POWER CONTROL

The Standard lists several forms of reactive power control:

- Constant power factor mode
- Constant reactive power mode
- Voltage-reactive power mode
- Active power-reactive power mode

Constant reactive power is not thought to be a particularly useful control mode. Constant power factor is the broad category of control that includes unity power factor, which can be useful, but is limited by operating at a control point that is not based on feeder conditions. Duke is in the process of performing studies that will focus on voltage-reactive power mode and active power-reactive power mode for UDER. The Duke study will evaluate the application and consequences of these functions.

Part of the study effort is to determine if voltage regulation functions should be activated and how they should be configured. Before using these functions on a widespread basis, Duke Energy will evaluate the system impacts, identify any unanticipated effects, and then assess the control modes and settings. Because the impact of UDER reactive injection can be large, Duke limits the reactive capability that can be used for reactive power control to 0.95 power factor.

In North and South Carolina utility scale solar, UDER, is the majority of the solar capacity installed. Therefore, study efforts will focus on that type of facility. In due time, there should be some consideration for residential-scale inverters as well. The reactive control method and settings should consider existing operational requirements as well as mitigation of the high voltages that can occur with the addition of DER. No change can be made on one part of the system that does not affect another part. Therefore, the study will also consider the magnitude of influence the inverter has on voltage, reactive power flow impacts, remediation of impacts, and controlling the impact on the transmission system. Distribution Providers must comply with agreements and requirements of the transmission entities. As such, an evaluation of transmission impacts is important.

Significant technical studies are required to evaluate these functions and analyze the consequences. The studies began at the end of 2019 and will continue in 2021. This will continue to be an agenda item for the TSRG meetings will focus on the most useful control modes and settings that are applied locally in the inverter and are autonomous.

Duke Energy has reviewed and considered all TSRG and submitted comments up to the date of this revision.

Interoperability requirements: To be determined.

Even with autonomous operation there will be some requirements to communicate the VAR priority mode and reactive power mode to Duke, and possibly other information. Because those requirements are not known at this time, Duke must perform additional analysis and interface testing for autonomous operation. For example, some DER require a 0-100% setpoint while others require an actual value in kVAR. In the future, there may be value in providing the necessary controls for remote utility control. That is second priority to autonomous operation, but that would require even more controls and monitoring. While priority can be enabled/disabled with a Binary Output, separate Analog Outputs must be used to set the individual control setpoints for each mode.

At this time, Duke does not have the capability to remotely control or manage distribution connected reactive power resources. However, there is some expectation that functionality may be necessary or available within the life of the DER. Facilities may want to make provision for interoperability capabilities that include both autonomous operation as well as remote control and adjustment of setpoints.

Verification and test requirements: To verify DER compliance to this requirement, Duke will require evaluation of the volt-var settings and field settings verification. Due to complication of performing voltage tests in the field, Duke does not plan to require field commissioning test on this topic. Operational data may be required to evaluate the DER's performance meeting this requirement.

Additional analysis must be performed before finalizing the Verification and test requirements.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface, and integrating verification requirements into the overall commissioning test program.

SECTION 5.4 – VOLTAGE AND ACTIVE POWER CONTROL

The main requirement here involves subsection 5.4.2, Voltage-active power mode. The voltage-active power mode serves as a backup to voltage control. Should an unexpected high voltage condition arise, or the voltage cannot be controlled by the local reactive resources, the voltage-active power control will reduce the DER active power to assist with voltage control

The settings and specifications for voltage-active power control are included with the study discussed for Section 5.3.

Interoperability requirements: To be determined.

Even with autonomous operation there will be some requirements to communicate the mode and possibly other information. Because those requirements are not known at this time, Duke must perform additional analysis and interface testing for autonomous operation.

Duke has the initial I/O points for active power control. The SCADA interface required and operations and functional requirements are still to be determined.

In the future, there may be value in providing the necessary controls for remote utility control. That is second priority to autonomous operation, but that would require even more controls and monitoring. While the mode can be enabled/disabled with a Binary Output, separate Analog Outputs must be used to set the individual control setpoints.

Verification and test requirements: To verify DER compliance to this requirement, Duke will require evaluation of the volt-watt settings and field settings verification. Due to complication of performing voltage tests in the field, Duke does not plan to require field commissioning test on this topic. Operational data may be required to evaluate the DER's performance meeting this requirement.

Additional analysis must be performed before finalizing the Verification and test requirements.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface, and integrating verification requirements into the overall commissioning test program.

SECTION 6.2 – AREA EPS FAULTS AND OPEN PHASE CONDITIONS

Duke Energy has not determined the guidelines for this section. While the Standard may be accepted as written, there may need to be clarifications.

This is a sub-task of an ongoing project involving the Protection and Transmission Planning groups. There is an enormous effort to model the system, perform iterative studies, perform the research, and evaluate protection settings. Duke Energy is working to determine the best DER recloser protection elements to optimize protection and ride-through performance and establish the abnormal operating performance Categories.

Interoperability requirements: To be determined.

Duke Energy must evaluate if there are any interoperability requirements for this section.

Verification and test requirements: The existing inspection and commissioning process covers the verification of this requirement. Duke plans to continue the practice and refine the process as necessary following the commissioning test requirements in IEEE 1547.1.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface.

SECTION 6.3 – AREA EPS RECLOSING COORDINATION

Duke Energy has not determined the guidelines for this section. While the Standard may be accepted as written, there may need to be clarifications.

This is a sub-task of an ongoing project involving the Protection and Transmission Planning groups. There is an enormous effort to model the system, perform iterative studies, perform the research, and evaluate protection settings. Duke Energy is working to determine the best DER recloser protection elements to optimize protection and ride-through performance and establish the abnormal operating performance Categories.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: For large scale DER that is equipped with a Duke PCC recloser, such coordination will be considered under the Duke Energy DER Enterprise Standards. For other DER, Duke will follow the commissioning tests requirements in IEEE 1547.1.

Implementation of this section requires publishing the final position.

SECTION 6.4.1 – MANDATORY VOLTAGE TRIPPING REQUIREMENTS

Duke Energy has not determined the guidelines for this section.

This is a sub-task of an ongoing project involving the Protection and Transmission Planning groups. There is an enormous effort to model the system, perform iterative studies, perform the research, and evaluate protection settings. Duke Energy is working to determine the best DER recloser protection elements to optimize protection and ride-through performance and establish the abnormal operating performance Categories. As placeholders, the present trip setpoints are added to the Guidelines.

Consensus was reached with Transmission System Planning and Operations for POI Recloser voltage and frequency settings and time delays that provide adequate ride-through for BES events. The team is still reviewing the impact to system protection with the proposed settings.

For new DER installations, the present voltage tripping setpoints are provided in the table below.

Parameter	Voltage	Time
Undervoltage, UV Level 1	0.88 pu	10 cycles
Undervoltage, UV Level 2	0.5 pu	6 cycles

Overvoltage, OV Level 1	1.1 pu	10 cycles
Overvoltage, OV Level 2	1.2 pu	6 cycles

Interoperability requirements: To be determined.

It is expected that these values will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: The existing inspection and commissioning process covers the voltage trip settings field verification and Duke plans to continue that practice. Due to complication of performing abnormal voltage tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

SECTION 6.4.2 – VOLTAGE DISTURBANCE RIDE-THROUGH REQUIREMENTS

Duke Energy has not determined the guidelines for this section, but these requirements are being developed concurrently with Section 6.4.1 – Mandatory voltage tripping requirements.

See Section 1.4 for the abnormal performance category.

Interoperability requirements: To be determined.

It is expected that these values will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: To verify DER compliance, Duke will require evaluation of the DER ride-through settings and field setting verification. Due to complication of performing abnormal voltage tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic.

Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

6.4.2.6 Dynamic voltage support

At least one Duke region requires dynamic reactive compensation for transmission connected DER. Application for the distribution system is still under evaluation.

SECTION 6.5.1 – MANDATORY FREQUENCY TRIPPING REQUIREMENTS

Duke Energy has not determined the guidelines for this section, but these requirements are being developed concurrently with Section 6.4.1 – Mandatory voltage tripping requirements. As placeholders, the present trip setpoints are added to the Guidelines.

For new DER installations, the present frequency tripping setpoints are provided in the table below.

Parameter	Frequency	Time
Underfrequency, UF	57 Hz	10 cycles
Overfrequency, OF	60.8 Hz	10 cycles

Interoperability requirements: To be determined.

It is expected that these values will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: The existing inspection and commissioning process covers the frequency trip settings field verification and Duke plans to continue that practice. Due to complication of performing abnormal frequency tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

SECTION 6.5.2 – FREQUENCY DISTURBANCE RIDE-THROUGH REQUIREMENTS

For sections 6.5.2.1 through 6.5.2.4, concerning frequency ride-through:

Duke Energy has not determined the guidelines for this section, but these requirements are being developed concurrently with Section 6.4.1 – Mandatory voltage tripping requirements.

The Standard also includes several subsections related to frequency. Although Duke Energy considers these requirements mainly as functional specifications for the inverter, Duke Energy does have additional requirements or clarifications.

6.5.2.5 Rate of change of frequency (ROCOF)

UL certification testing should verify the inverter will ride through a 3 Hz/s excursion. That being the case, no generator on the utility system shall intentionally trip for ROCOF using protective relaying or DER controller functions. DER tripping for ROCOF, if available, should be off or disabled. The DER shall certify that protective relay settings & controller settings do not intentionally trip for ROCOF.

This function, either at the inverter or the utility PCC recloser, is still under evaluation. Duke anticipates adopting the 1547 requirements if that is supported by the ongoing project.

6.5.2.6 Voltage phase angle changes ride-through

This function, either at the inverter or the utility PCC recloser, is still under evaluation. Duke anticipates adopting the 1547 requirements if that is supported by the ongoing project.

6.5.2.7 Frequency-droop (frequency-power) capability

This function is still under evaluation. Per Standard table 22, a specification of the droop, deadband, and associated parameters is required for Category III.

6.5.2.8 Inertial response

Duke Energy has not determined the guidelines for this subsection. This capability is not required by the Standard but is permitted.

Interoperability requirements: To be determined.

It is expected that these values for Section 6.5.2 will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: To verify DER compliance, Duke will require evaluation of the DER ride-through settings and field setting verification. Due to complication of performing abnormal frequency tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

SECTION 7.2.2 – RAPID VOLTAGE CHANGES

Duke has an existing process that is part of the system impact study to assess the risk of Rapid Voltage Changes (RVC) and require mitigation if necessary. Duke considers that the existing RVC criteria is consistent with the Standard and does not plan further evaluation.

Interoperability requirements: To be determined.

Based on the type of inrush mitigation used, there could be some status points that are useful for situational awareness. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements.

Verification and test requirements: The installation evaluation is currently included in the scope of Duke's interconnection inspection process, but the performance of the mitigation is not currently tested. A power quality meter is required for the field tests. Duke plans to evaluate the DER RVC impact and mitigation performance by reviewing the data collected during the commissioning test (such as cease-to-energize test).Duke will develop a test procedure and criteria to evaluate the performance of a RVC mitigation solution as part of the commissioning tests.

Implementation of this section requires applying the interoperability functionality in the local interface and integrating verification requirements into the overall commissioning test program.

SECTION 7.2.3 – FLICKER

Duke Energy adopts these requirements as written in the Standard. Note that Duke also applies IEEE 1453 recommended practices.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review design document and equipment specification to evaluate the potential flicker cause DER. A power quality meter is required for the field tests. Duke plans to follow the commissioning tests requirements in IEEE 1547.1. Operational data collection after a DER or system event may be required to validate proper DER operation.

This section is ready to be implemented.

SECTION 7.3 – LIMITATION OF CURRENT DISTORTION

Duke Energy adopts these requirements as written in the Standard. The industry has found that the inverter designs are reaching and exceeding the harmonic monitoring capabilities of existing measurement devices. Therefore, Duke Energy requires the DER owner to mitigate all order harmonics to no greater than 0.3% if the harmonics affect other customers. Harmonic limits shall be aggregated and applied during the DER hours of operation.

Interoperability requirements: No specific requirements for this section. Installation of a power quality meter is already part of the required design for DER 1 MW and greater.

Verification and test requirements: Duke plans to follow the commissioning tests requirements in IEEE 1547.1.

This section is ready to be implemented.

SECTION 7.4.1 – LIMITATION OF OVERVOLTAGE OVER ONE FUNDAMENTAL FREQUENCY PERIOD

Duke Energy adopts these requirements as written in the Standard.

Part of 7.4.1 is based on the inverter design and operation and part is based on the specific design of the interconnection and the Area EPS itself. The ability of the inverter to detect and limit overvoltage will be verified by UL certification testing. However, the DER facility must still be analyzed during system impact study to verify the impact of the combined inverter and Area EPS is below the limits of the Standard. The limits defined in parts a) and b) must be verified by power system study.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to rely on UL certification testing, review type tests results, and examine design documents to evaluate the potential overvoltage contribution from DER. Duke plans to develop a test procedure and criteria for transient overvoltage during the commissioning test. A power quality meter is required for the field tests. Duke plans to follow the commissioning tests requirements in IEEE 1547.1.

This section is ready to be implemented.

SECTION 7.4.2 – LIMITATION OF CUMULATIVE INSTANTANEOUS OVERVOLTAGE

Duke Energy has not determined the guidelines for this section. More industry experience or analysis could be essential to address this issue. Duke does not plan to implement this section until IEEE 1547.1 is revised and UL 1741 certification tests include this verification. At that time, Duke expects to adopt these requirements as written in the Standard.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review type tests results and design documents to evaluate the potential overvoltage contribution from DER. Duke plans to develop a test procedure and criteria for transient overvoltage during the commissioning test. A power quality meter is required for the field tests. Duke plans to follow the commissioning tests requirements in IEEE 1547.1.

Implementation of this section requires publishing the final technical position.

SECTION 10.3, 10.4 – NAMEPLATE AND CONFIGURATION INFORMATION

These sections address the two broad types of information available through the local DER communication interface. The following terms are listed in decreasing order of magnitude. The value of each parameter in the list is greater than or equal to the value of the parameter below it:

Nameplate Apparent Power Maximum Rating
Configuration Apparent Power Maximum Rating
Nameplate Active Power Rating (unity power factor)
Configuration Active Power Rating (unity power factor)

The list above does not address all the terms in the table. Such a specification is not necessary of every term, but helpful to clarify for some. Duke will consider addressing other terms as needed. Consequently, operational limits and settings, such as the Active Power Limit, cannot be greater than the ratings (not applicable to abnormal or protection settings).

Ratings are considered a permanent characteristic of a device or a system and are characterized by:

- Rating is the full capacity of the equipment or system.
  - The rating is the <u>most</u> capacity the system is <u>designed</u> to provide
- Rating represents a continuous capacity. Operation at the Rating can continue for indefinitely long periods without exceeding design limits and without reducing the life or maintenance interval.
  - Also, there can be short-term ratings that are time limited. Operation within the parameter and time limit does not exceed design limits or negligibly reduce the life or maintenance interval.

- Rating is the base upon which other model, analysis, and inverter parameters are referenced.
- Ratings are a common way to identify and classify devices.

Limits are not included in these sections of the Standard. However, their relationship to and differences from ratings are important. Limits are adjustable, provide boundaries not to be exceeded, and are less than or equal to ratings. Limits are characterized by:

- Limits impose boundaries on device operation, often to restrict operation within ratings.
- Limits can be established or defined by contractual, system design, or physical equipment restrictions.
- Limits are set for a controlled variable and must not be exceeded (e.g. boundary condition).
- Limits are often stated as a percent of the rating (therefore necessitating a fixed rating value).

The Nameplate Active Power Rating is an important design parameter for the DER, but also as an important base parameter for modeling. The same for Nameplate Apparent Power Maximum Rating, for some equipment or models, parameters may be specified in terms of percent of Nameplate Apparent Power or Nameplate Active Power Rating. In cases where operation to the full Nameplate Active Power Rating is not acceptable for the application, then the Configuration Active Power Rating can be set to establish a lower rating. While the minimum of these two values sets the overall rating, it can be important to distinguish between these when it comes to equipment specifications and modeling.

UNADDRESSED REQUIREMENTS OF IEEE 1547-2018

The remaining IEEE 1547-2018 clauses and sections not discussed above will be undertaken following the completion of the higher priority topics. Concerning the clauses and sections not addressed in this document, Duke Energy expects that the DER shall conform to the Standard itself as written.

APPENDIX – IEEE 1547-2018 BENCHMARKING

Duke Energy requested that Navigant Consulting, Inc. to facilitate the stakeholder discussion at the January 2020 TSRG meeting and to perform benchmarking. The following table was developed by Navigant Consulting, Inc.

TABLE B.1. BENCHMARKING OF IEEE 1547-2018 FUNCTIONALITIES IMPLEMENTATION

IEEE 1547 Section	Topic	Duke Order (pre-stakeholder)	Minnesota/ Colorado (Xcel Energy)	Ameren / MISO
6.4.2	Voltage disturbance ride-through requirements	1	1	1
5.3	Voltage and reactive power control	1	1	1
6.5.2	Frequency disturbance ride-through requirements	2	1	1
6.4.1	Mandatory voltage tripping requirements (OV/UV)	1	1	2
5.4.2	Voltage-active power control	1	1	2
6.5.2.7	Frequency-droop (frequency-power) capability	2	1	2
6.5.1	Mandatory frequency tripping requirements (OF/UF)	2	1	2
5.2	Reactive power capability of the DER	1	1	
4.5	Cease to energize performance requirement [Reliability]	3	2	
4.6.1	Capability to disable permit service	3	2	
4.6.2	Capability to limit active power	3	2	
4.10.2	Enter service criteria	4	3	2
7.2.2	Power Quality, Rapid voltage change (RVC)	1	3	
4.10.3	Performance during entering service	4	3	
4.10.4	Synchronization	4	3	
4.2	Reference points of applicability (RPA) [Interconnection]	4	3	
6.5.2.5	Rate of change of frequency (ROCOF)	4	4	1
4.10	Enter service [Reliability] // 6.6 Return to service after trip	4	4	2
6.4.2.6	Dynamic voltage support		4	2
4.3	Applicable voltages [Manufacturer]	4	4	
4.11.3	Paralleling device	4	4	
6.2	Area EPS faults and open phase conditions [Reliability]		4	
6.3	Area EPS reclosing coordination [Reliability]		4	

IEEE 1547 Section	Topic	Duke Order (pre-stakeholder)	Minnesota/ Colorado (Xcel Energy)	Ameren / MISO
10.2	Monitoring, control, and information exchange requirements		4	
10.5	Monitoring information		4	
10.1	Interoperability requirements		4	
10.3	Nameplate Information		4	
10.4	Configuration information		4	
10.6	Management information		4	
10.7	Communication protocol requirements		4	
10.8	Communication performance requirements		4	
10.9	Cyber security requirements		4	
11	Test and verification		4	
8.2	Intentional islanding		4	
11.4	Fault current characterization		4	
9	Secondary network		4	
4.6.3	Execution of mode or parameter changes [Manufacturer]		4	
6.5.2.6	Voltage phase angle changes ride-through	2		1
6.4.2.5	Ride-through of consecutive voltage disturbances			1
7.2.3	Power Quality, Flicker	1		
7.4	Limitation of overvoltage contribution	1		
6.5.2.8	Inertial response			
7.3	Limitation of current distortion			
8.1	Unintentional islanding			
4.7	Prioritization of DER responses			
4.8	Isolation device [Interconnection]			
4.11.1	Protection from electromagnetic interference			
4.11.2	Surge withstand performance			
4.12	Integration with Area EPS grounding [Reliability]			
4.13	Exemptions for Emergency Systems and Standby DER			
4.9	Inadvertent energization of the Area EPS [Interconnection]			

1

Duke Energy
DER Interconnection
Technical Standards Review Group (TSRG)

DUKE ENERGY

TSRG Agenda Process

- TSRG Members may propose agenda items
- Agenda items may be submitted until the Duke Lead and Industry Lead set the agenda, which is usually two weeks prior to the date of the meeting. It is uncommon to accept substantial agenda items within the two weeks prior to a TSRG meeting
- Duke Lead is responsible for collecting the agenda items proposed by Duke
- Industry Lead will collect the agenda items proposed by the industry
- Excess agenda items may be postponed and rescheduled for a future meeting at the discretion of the Duke Lead and Industry Lead
- Agendas are set by the Duke Lead and Industry Lead and consider balancing the utility and industry agenda items while ultimately selecting the topics agreed upon as most important
- While the discussion at any TSRG meeting need not be confined to the topics set forth in the agenda, the members may not be prepared to speak to other topics in detail and non-agenda topics that arise may be postponed and later assigned to future meeting agendas